Davis

DEVELOPMENT OF INSTRUMENTATION FOR DROP WEIGHT IMPACT TESTING

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DEVELOPMENT OF INSTRUMENTATION FOR DROP WEIGHT IMPACT TESTING

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1.0 INTRODUCTION

1.1 BACKGROUND

W.R. Davis Engineering Limited (DAVIS) was contracted by Energy, Mines and Resources, Canada (EMR), to design and develop instrumentation to facilitate drop weight impact testing. The instrumentation is to allow the measurement of the mechanical properties, specifically the toughness of various steels, that are developed for marine applications. This report provides a complete description and discussion of the developed instrumentation.

The instrumentation provided by DAVIS will be able to measure very high strain rates. It is a four channel data acquisition system that can provide the following information:

- load-time trace
- crack opening displacement
- hammer velocity
- hammer position
- stress

Graphical information can be output to a computer printer.

1.2 OBJECTIVE

The primary objective of the project is to develop instrumentation which will allow the measurement of mechanical properties, specifically, the toughness of various steels that will be developed for marine applications.

1.3 LIST OF ITEMS PROVIDED

1.3.1 Hardware

The following hardware is provided for EMR:

1) A PC AT compatible computer system consisting of:

- 80286 processor, 12 MHZ, 0 wait state
- 80287 math co-processor, 12 MHZ
- 1 MB memory
- 5.25" 1.2 MB floppy disk drive
- 3.5" 1.44 MB floppy disk drive
- EGA card
- 14" EGA colour monitor
- 2 serial ports
- 2 parallel ports
- National Instruments GPIB parallel interface
- Metrabyte Model PIO12 parallel input/output interface

2) A DAVIS Signal Conditioning, Transducer Interface Box

3) A Lecroy 2005 data acquisition system consisting of:

- Lecroy Model 6810 4 channel digitizing module
- Lecroy Model 8901A GPIB interface module
- Lecroy Model 8013A benchtop instrument mainframe

4) A Raven PR-9101 Multi-Mode 9-Pin Printer

5) MTS Temposonics Linear Displacement Transducer with Digital Interface Box

6) Cables for:

- Clip 1 and Clip 2 gauges
- accelerometer
- Tup gauge
- height in (MS to DA-15 connector)
- height out (DC37 connector)
- GPIB cable (from Lecroy to computer)

1.3.2 Software

The following software is provided on diskette:

1) NI-488 Distribution Disk for GPIB-PCII/IIA, MS-DOS Handler; BASIC A, Quick BASIC, Microsoft C & Universal Interfaces (1 disk)

2) Halo '88 Graphics Kernel System

   a) Halo '88 for MS FORTRAN (1 disk)
   b) Halo '88 Device Driver Update 1 (1 disk)
   c) Halo '88 Device Drivers (6 disks)

3) DAVIS Height Measurement (1 disk)

4) Lecroy Waveform Catalyst Software

   a) 6900-3S Program Disk (1 disk)
   b) 6900-3S Boot Disk (1 disk)
   c) 6900-3S Library Disks (6 disks)

1.3.3 Manuals

The following manuals are provided:

1) DAVIS Manual

2) Halo '88 Graphics Kernel System

a) Language and Device Reference
b) Library References

3) Lecroy Model 6810 Waveform Recorder

4) Lecroy Waveform-CATALYST Function Library Manual, Version 3.03

5) Lecroy Waveform-CATALYST Multichannel Digital Oscilloscope and Instrument Control System User's Manual, Version 3.03

6) Lecroy CAMAC Instrument Mainframes, Models: 8013A, 1434A, and 8025

7) Lecroy Model 8901A CAMAC to GPIB Interface

8) National Instruments GPIB-PC Instrumentation Interface Manual

9) Raven PR-9101 Printer

10) MCK-101SX/FT Keyboard User's Manual

11) Penor EGA Colour Monitor Owner's Manual

12) 12 MHZ Zero-Wait 80286 Turbo Main Board, MBVLSI-168B

13) DT-3767 Floppy Controller/IDE Drive Interface Adapter Card

14) ATI EGAWONDER Operation Manual

15) MTS Temposonics Linear Displacement Transducer System
(In Appendix B of DAVIS Manual)

2.0 INSTRUMENTATION REQUIREMENTS AND THEORY

This section discusses the impact test machine's instrumentation requirements, and the procedures and problems associated with the measurement of drop weight impact tests.

2.1 INSTRUMENTATION COMPONENTS

Basic instrumented impact testing requires an impact machine, load sensors, signal conditioning for load sensors, velocity measurement, height measurement equipment, and signal display components.

The load sensors are provided by EMR. They are semiconductor strain gauges cemented to the test specimen and the impact machine. The gauges are connected to form a Wheatstone bridge circuit.

The load sensor is an instrumented tup. The load signal is recorded from an existing strain gauge circuit mounted on the side face of the tup. These gauges are positioned to sense the compressive force between the impact machine and specimen. The gauges are connected to form a Wheatstone bridge circuit, consisting of four active gauges, two aligned with maximum principal strain and two "Poisson" gauges.

A clip gauge will be developed at EMR and will consist of a small omega shaped ring. The diameter of the ring will be approximately 10mm, with strain gauges on the outside of the spring. Calibration will be done by EMR. Again, the strain gauges are connected to form a Wheatstone bridge.

To operate successfully as load sensors, the semiconductor strain gauges require a precision power supply which has a noise contribution of less than 0.5 percent of the full scale output. The typical full scale output of a semiconductor strain gauge is 350mV. Therefore, the noise contribution of the excitation power supply should be less than 1.75mV.

A linear height transducer is required to measure the position of the hammer before a test. The height range is to be a minimum of 0 to 2m. The height transducer will not be used to measure the height position during impact. Precision is to be better than ±1mm.

A device must be provided to measure the hammer velocity or position just before and during the test. An accelerometer can be mounted on the weight of the impact tester to provide the measurement of velocity. This will require signal conditioning for the accelerometer. Furthermore, software will have to be developed to integrate the signal from the accelerometer to provide a velocity measurement. Software to perform this task is not provided by DAVIS.

The signal display component for instrumented impact testing is usually in the form of an oscilloscope system. An oscilloscope can provide good signal resolution with respect to time, and very suitable for recording transient waveforms. Storage capability and graphical output to a printer or plotter can provide a permanent record for analysis.

The signal display component requires a command signal (external trigger) for the coordination of the scope trace. A command signal tells the oscilloscope to begin measurements. This command signal usually occurs at an instant before the tup makes initial contact with the test specimen. The commonly used technique for the generation of the external trigger signal is one that employs a photoelectric device. This technique uses a high-intensity light source directed at a photomultiplier so that the hammer (instrumented tup assembly) intercepts the light beam just prior to making contact with the specimen and thereby generates a signal for triggering of the recording system.

2.2 FREQUENCY RESPONSE

Frequency response of electronic components is an important parameter when performing instrumented impact tests. All instrumentation has limited frequency response.

The 3-dB attenuation frequency is the most commonly used value for the specification of frequency response. The 3-dB attenuation corresponds to the frequency for which the output measures 0.707 times the input, or approximately a 30 percent reduction in the amplitude of the signal. For most instrumented impact tests, however, assurance of a 10 percent or less amplitude reduction ($f_{0.9\ dB}$) is required.

An electronic component can also be represented in terms of rise time rather than frequency response. Rise time can be defined as the time required for a signal to increase from 10 to 90 percent of the full amplitude. The relationship between signal frequency ($f_{0.9\ dB}$) and rise time t_r for a sinewave is

$$t_r \approx \frac{0.35}{f_{0.9\ dB}} \qquad (2.1)$$

The general form of the load signal obtained from an instrumented impact test is similar to a sinewave. Equation 2.1 can be used to determine the required frequency response from the rise time of the expected signal. The required frequency response from Equation 2.1, for a lower impact test rise time of 10 μs, is

$$f_{0.9\ dB} = \frac{0.35}{10\mu s} = 35\ kHz$$

This requires the frequency response of the amplifiers to be at least 35 kHz. The semiconductor strain gauges have an upper limit frequency response of almost 100 kHz.

2.3 OSCILLATIONS

When a strain gauge is attached to the tup or striker position of the impact hammer, the signal generated by the strain gauges represents a complex combination of the following components:

a) The true mechanical response of the specimen.

b) Inertial loading of the tup as a result of acceleration of the specimen from rest.

c) Low frequency fluctuations caused by stored elastic energy and reflected stress waves.

The latter is usually minimized through use of high-gain strain gauges (semiconductor) to achieve a relatively large signal-to-noise ratio. In some instances, filtering is employed to suppress the noise.

The inertial loading on the tup can be viewed as the force caused by rigid body acceleration of the specimen from a rest position to a velocity near that of the impacting hammer - tup assembly. This component dominates the initial 20 to 30 μs portion of the tup signal and is represented by the first fluctuation (oscillation) of the load-time profile. The magnitude of this inertial oscillation is related to the acoustic-impedance of the tup and specimen and the initial impact velocity. The inertial load is a maximum at the moment of impact and rapidly decreases as the velocity of the specimen is increased.

The first oscillation on a tup signal can be considered primarily the result of inertial effects and subsequent oscillations the result of stored elastic energy and reflected stress waves. This is discussed because it may appear in test results and may not be truly representative of the test. However, further discussion on this matter is beyond the scope of this report.

2.4 SAMPLING FREQUENCY

The rise time of an impact signal can be as low as 10 μs as discussed in Section 2.2. It was calculated that for such a rise time to be properly represented in a measured transient impact signal, a $f_{0.9\,dB}$ of 35 kHz is required. The Nyquist rate states that the sampling frequency should be twice that of the highest frequency expected to properly reconstruct the signal. This would imply a sampling frequency of 70 kHz. However, the strain gauges have a frequency response of almost up to 100 kHz. Therefore, to avoid aliasing, sampling should be performed at a frequency of greater than 200 kHz (5 μs). A sampling frequency of 1 MHz was requested by EMR.

2.5 DATA ACQUISITION

The specification provided by EMR states that four selectable channels, expandable up to eight must be provided. The data acquisition has to be simultaneous for all channels, and resolution must be at least 12 bit. The memory size requested by EMR was 2000 valid data points on each channel for one test.

2.6 DATA MANIPULATION AND ANALYSIS

EMR indicated that display and analysis of the acquired data must be performed on an IBM AT compatible computer. The software's future development or analysis will be performed by EMR. The data files have to be stored in such a way that they could be read or modified by commercial graphic packages.

3.0 SYSTEM OVERVIEW

In order to meet all of the requirements of Section 1 and 2, a multi-channel data acquisition system is required. The following sections discusses each area of the system; devices and transducers used, and techniques and circuits.

3.1 GENERAL

The system consists of a PC AT compatible computer and an external data acquisition unit.

The PC AT compatible computer has the following features and functions:

- 80286 processor, 12 MHz, 0 wait state
- 80287 math co-processor, 12 MHz
- 1 MB memory
- 5.25" 1.2 MB floppy drive
- 3.5" 1.44 MB floppy drive
- EGA card
- 14" EGA colour monitor
- 2 serial ports
- 2 parallel ports
- Raven PR-9101 Multi-Mode 9-pin dot matrix printer
- National Instruments GPIB parallel interface to the data acquisition unit
- Metrabyte Model PI02 parallel input/output interface.

The data acquisition unit is made by Lecroy and a data acquisition interface box designed by DAVIS houses signal conditioning and interface modules for transducers. The following measurements can be made:

- tup strain gauge input
- 2 clip gauge inputs
- velocity input
- position input

The system is illustrated in Figure 3.1.

3.2 TUP GAUGES AND CLIP GAUGES

The tup gauges are provided by EMR. The tup gauges are Wheatstone bridge type. The information provided by EMR stated that they are semiconductor strain gauges manufactured by Entran Devices (ES-350) or Micro Measurements (EA-06-125TG-350). The required excitation voltage is 10 VDC and the nominal bridge resistance is 350 Ohms. The full bridge circuit consists of four active gauges, two

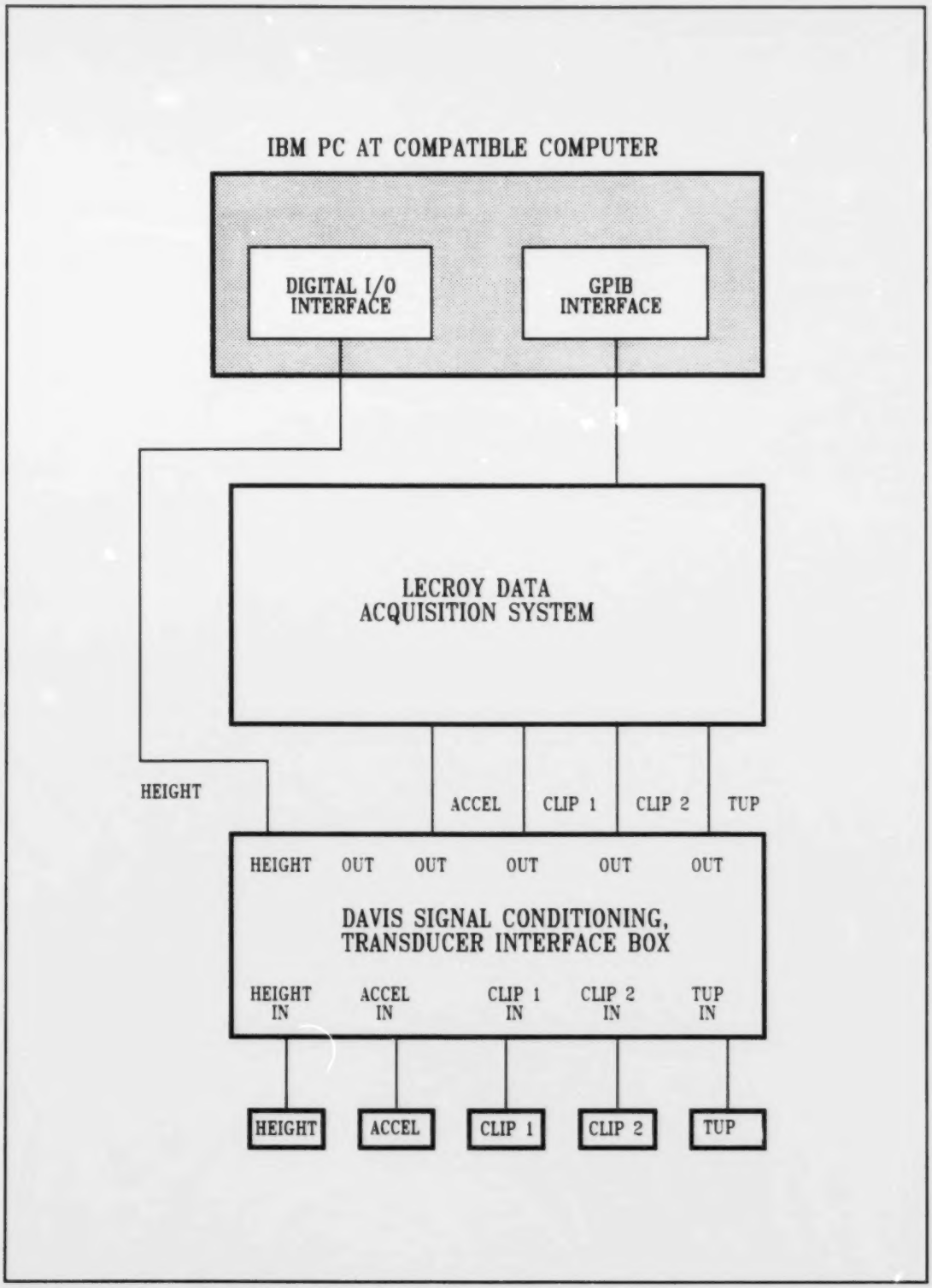


FIGURE 3.1 SYSTEM BLOCK DIAGRAM

aligned with maximum principle strain, and two "Poisson" gauges.

Excitation voltage is provided by a simple but effective +10 VDC power supply circuit. Fine tuning of the excitation voltage is possible by adjusting a potentiometer. The circuit can be found in the Appendix.

In testing of this circuit, the noise contribution of the +10 VDC power supply was measured to be less than 0.18 percent of the full scale output of the strain gauge or 630.6 μV. This exceeds the requirement of Section 2.1, making it suitable for use as an excitation voltage source.

Amplification of the strain gauge outputs are provided by the data acquisition system (see Section 3.2.4).

3.3 ACCELEROMETER

The system utilizes an Endevco Model 7231C-750 accelerometer for the measurement of velocity. The accelerometer is a rugged, undamped, medium g-level piezoresistive accelerometer designed for automotive crash test studies. The Model 7231C utilizes two active silicon strain gauges and two fixed resistors arranged in a Wheatstone bridge configuration. The model has the following characteristics:

- range +/- 750 g
- sensitivity 0.2 mV/g
- frequency response 0-2000 Hz
- mounted resonant frequency 25000 Hz
- excitation +10 VDC
- output resistance 525 ohms

The output of the accelerometer is low voltage, therefore it was necessary to provide amplification before the signal was input to the data acquisition system. The signal conditioning was performed by an Analog Devices Model 3B18-01 Wide Band Strain Gauge Signal Conditioner. The signal conditioner is installed in the DAVIS Signal Conditioning, Transducer Interface Box. This model has the following specifications:

- input range ± 30 mV at 3 mV/V sensitivity
- output range 0 to 10 V
- bridge excitation + 10 V
- bridge resistance range 300 ohms to 1000 ohms
- bandwidth 20 kHz

The signal conditioner performance exceeds the performance required by the accelerometer.

3.4 DROP WEIGHT HEIGHT MEASUREMENT

The system measures the weight position (height of drop weight) by means of a non-contact displacement transducer.

The transducer is manufactured by MTS. The model is Temposonics Linear Displacement Transducer System with Direct Digital Output. The height measurement system has the following specifications:

- 84 inch stroke length
- 15 bit natural binary output format

The system measures the time interval between an interrogation pulse and a return pulse. The interrogation pulse is transmitted to the transducer. The return pulse is created by the magnet, which is located at the position to be measured. The time difference between pulses is converted to a natural binary direct digital output signal.

The following components make up the height measurement system:

- a linear displacement transducer (LDT)
- a digital interface box (DIB)
- digital counter card

The linear displacement transducer is mounted on a vertical beam beside the drop weight system, and the magnet is mounted on a cantilever that is attached to the drop weight. When the drop weight is lowered or raised, the magnet follows the movement and the transducer "measures" the position.

The digital interface box contains the intelligence for interrogation and return pulse sensing of the transducer. It is mounted to the floor near the base of the impact machine.

The digital counter card measures the on-time of the interface box pulse duration signal, and outputs a 15 bit complemented binary output. A maximum of 32767 counts are possible, with a resolution of 0.004 inch per count. However, the maximum height that can be measured is 84 inches, limited by the transducer.

The digital output from the counter card is then input to a Metrabyte 24 bit Digital Input/Output Board Model PI012. Software was written in Turbo PASCAL to control the ports of the Metrabyte Board. The software first writes to the control register of the parallel digital I/O card to set the configuration. The configuration is set so that ports PA and PB are inputs. The software then accesses the PA port and PB port to retrieve the height in binary form. The software finally converts the binary number to a height measurement in inches and metres. The program is listed on the next page.

It should be noted that the operation of the height transducer is independent of the Lecroy data acquisition system. In other words, they cannot be operated at the same time.

The software is very flexible in that you can change the zero point of the drop weight system. For different sizes of specimens the zero height will change. The zero height is set for the test specimen that results in the lowest height.

```
{                    W.R. DAVIS ENGINEERING LIMITED, OTTAWA, CANADA                    }
{                                  JULY 1990                                           }
{                                                                                      }
{          Height Measurement Program for Drop Weight Impact Tester                    }
{                                                                                      }
{                              DAVIS File Number: 90110                                }
{                                                                                      }
{     This program was written for Energy, Mines and Resources, Canada.               }
{                                                                                      }
{ The purpose of this program is to access the Metrabyte Digital Input                 }
{ Output Board. The height of the drop weight is measured by an MTS                    }
{ Temposonics Linear Transducer. The output of the transducer is in a form}
{ a 15 bit binary number, and is input to the PA and PB port of the                    }
{ Metrabyte board. This program reads the PA and PB ports and converts the}
{ binary number into a decimal number corresponding to the height of the               }
{ drop weight in inches and metres.                                                    }
{                                                                                      }
{ Variables:                    X: lower eight binary significant digits               }
{                               Y: upper seven binary significant digits               }
{                     Height_inch: measured height in inches                           }
{                    Height_metre: measured height in metres                           }
{                    Scale_Factor: this is the scale factor of the height              }
{                                  transducer's digital output, 0.032316"/count        }
{                           Reply: a reply from the user to activate the height        }
{                                  measurement, a "1" is true, anything else           }
{                                  is false                                            }
{                       i,j,k,l : counters to slow down the sampling of the            }
{                                  height                                              }
{}                                                                                     }
{}
program Height(input,output);
{}
var                  X,Y,i,j,k,l,m : integer;
    Height_inch,Height_metre : real;
                           Reply : integer;
                    Scale_Factor : real;
{}
begin
     Scale_factor:=0.03231598;
     ClrScr;
     writeln ('W.R. DAVIS ENGINEERING LIMITED, OTTAWA'); {Introduction to progra
n}
     writeln ('Drop Weight Impact Tester');
     writeln ('Drop Weight Height Measurement');
     writeln;
     {prompts user with instructions}
  {if a "1" is typed, program continues, any other key will abort program}
     writeln ('Type "1" followed by ENTER if you want to read the height of the
drop weight. ');
     writeln ('To abort the height measurement, type any key.');
     writeln ('Please enter reply:');
     read (reply);
     if reply = 1 then
         repeat                        {the height is sampled until a key is pressed}
            port[771]:=147;            {write to control register and set configuration}
                                       {Ports PA, PB, and PC are inputs}
            X:=port[768];              {read port PA}
            Y:=Port[769];              {read port PB}
            writeln;
            Height_inch:=(X+Y*256)*Scale_Factor;    {convert to inches}
            Height_metre:=Height_inch * 0.0254;     {convert to metres}
```

```
            ClrScr;                                    {display height}
            writeln ('The measured height is ',Height_inch:8,' inches.');
            writeln ('In metres, the height is ',Height_metre:10,' metres.');
            i:=0;              {counters slow down the sampling by the computer}
            while i < 32767 do
               i:=i+1;
            j:=0;
            while j < 32767 do
               j:=j+1;
            k:=0;
            while k < 32767 do
               k:=k+1;
            l:=0;
            while l < 32767 do
                  l:=l+1;
               until Keypressed;
         writeln;
         writeln ('Height measurement is aborted.');
         writeln ('Remember to record the height if a measurment was taken.');
         writeln ('Enter CAT at the C> prompt to activate the data acquisition s
oftware.');
end.
```

To change the zero height, one must modify the software. Knowledge of TURBO PASCAL is required. Measure the difference in height between the new test specimen and the specimen that the software was calibrated for. The following block must then be modified.

```
Writeln;
Height_inch:=(X+Y*256)*Scale_Factor; {convert to inches}
Height_metre:=Height_inch*0.0254; {convert to metres}
ClrScr;
```

In the line, Height_inch:=(X+Y*256)*Scale_Factor; the difference in height must be inserted at the end of the line (before semicolon). For example, for a test specimen which results in a height 2 inches higher than the calibrated zero height, the line should be edited to:

```
Height_inch;=(X+Y*256)*Scale_Factor-2;
```

This change can be made using an editor such as Turbo. A .COM file can then be compiled using TURBO PASCAL, and renamed to match the test specimen. One can then build up a library of height measuring programs applicable to certain sizes of test specimens.

3.5 DATA ACQUISITION

The data acquisition system is a 4 channel unit. The channels are as follows:

- tup strain gauge input
- clip gauge input
- clip gauge input
- accelerometer input

The data acquisition system is a Lecroy 2005, consisting of:

- one Lecroy Model 6810 4 channel, 12 bit, digitizing module
- one Lecroy Model 8901A GPIB interface module and GPIB cable
- one Lecroy Model 8013A benchtop instrument mainframe with extra front panels for unused slots
- one Lecroy 6900 Waveform - Catalyst software.

The data acquisition system is based on the Model 6810 Waveform Recorder. The module is a complete independent recording system, including wide range differential amplifiers, a high resolution analog to digital converter (ADC), triggering circuitry and on-board waveform memory. The module is a 12 bit resolution, high sample rate unit. Sample rates of up to 5 Megasamples per second are possible. The 6810 is provided with a 512 K sample memory. The memory is expandable to 8 Megasamples. If future testing requires more channels, another Model 6810 can be added to the CAMAC mainframe, to increase the number of channels to 8.

The waveform recorder module measures DC to 2.5 MHz signals, and each of the four differential input channels provides full scale ranges from 400 mV to 100V full scale. This eliminates the need for external signal conditioning for the semiconductor strain gauges. However, no bridge completion is provided for. The information provided by EMR states that the bridge circuit is made up of four active gauges, two aligned with maximum principal strain and two poisson gauges.

At a sampling frequency of 1 MHz, 128 K samples of memory is available for each channel. This exceeds the requirement requested by EMR in Section 2.5. Better resolution will result if the data acquisition system is set for a 0.2 μs period (5 MHz sampling frequency).

An external triggering device must be provided by EMR. The existing photoelectric device used by EMR can be used for external triggering.

Software to analyze the data acquired was not part of this contract. However, software was provided with the Lecroy data acquisition system. The Lecroy Waveform-Catalyst software provides a Function Library which will provide the user with most required functions to analyze data. In addition, Halo '88 Graphics Kernel software is provided.

Refer to instruction manuals, Lecroy Waveform-Catalyst Function Library Manual Version 3.03, and Halo '88 User Manuals for more information.

4.0 USER'S MANUAL

This section provides basic instructions on how to use the height transducer and data acquisition system. Full procedures are given for the height measurement. However, one is only referred to the Lecroy Operator's Manual on the use of the data acquisition system. The user is referred to examples to gain familiarity with the system.

4.1 HEIGHT MEASUREMENT

To activate the height measurement software, simply type HEIGHT at the C> prompt. You will then see the following on the computer screen:

W.R. DAVIS ENGINEERING LIMITED, OTTAWA
Drop Weight Impact Tester
Drop Weight Height Measurement

Type "1" followed by ENTER if you want to read the height of the drop weight.

To abort the height measurement, type any key. Please enter reply:

Type a "1" followed by ENTER to continue with height measurement program, or type any other key to abort the program. If a "1" followed by ENTER was typed, the screen will flash about every half second displaying the height measurement. When the user desires to stop the height program, the user hits any key and the program will abort, and the following will be displayed on the computer screen:

The measured height is _____ inches.
In metres, the height is _____ metres.

Height measurement is aborted.

Remember to record the height if a measurement was taken. Enter CAT at the C> prompt to activate the data acquisition software.

Record the height as the computer will not remember it. To activate the Lecroy data acquisition system, type CAT at the C> prompt.

4.2 LECROY DATA ACQUISITION SYSTEM

The data acquisition software is installed on the computer's hard disk. No set-up procedures are required. Software has also been provided on diskettes.

Refer to the following Operator's Manual to use the data acquisition system:

- Model 6810 Waveform Recorder
- Waveform-Catalyst Function Library Manual Version 3.03
- Waveform-Catalyst Multichannel Digital Oscilloscope and Instrument Control System User's Manual.

An excellent example to allow the user to become familiar with the system can be found on page 32 of the Model 6810 Waveform Recorder Manual.

Also included is the Halo 88 Graphics Kernel System. It contains a collection of graphic subroutines which lets you incorporate sophisticated computer generated images in your own applications. The library consists of more than 190 functions which eliminate the need for you to generate the source code needed to implement graphics while giving you maximum flexibility. Refer to the manuals provided for Halo 88.

4.3 ADJUSTMENT OF ACCELEROMETER'S SIGNAL CONDITIONER

The location of the Analog Devices Signal Conditioner is shown in Figure A1. On the top of the signal conditioner, there is a sliding door. Behind the sliding door are two potentiometers for zero and span trim. These user accessible span trim potentiometers provide a ±5 percent adjustment range to permit precise field calibration of the voltage output. See Appendix D for specification and more information.

4.4 BALANCING OF STRAIN GAUGES (TUP, CLIP 1, CLIP 2)

When the impact test system is at a rest position, one can adjust the rest position to be a level of zero volts (if required). This is not performed on the strain gauge itself but set using the Waveform-CATALYST software. This is performed by providing an offset in the Waveform-CATALYST Set-up Menu. This is line 9 of the 6810 CATALYST Set-up Menu Screen.

The colour coding for the strain gauges are as follows:

- red is 10 VDC excitation
- black is gnd for excitation
- white is + output
- green is - output (common).

These wires attach to the bridge circuit provided by EMR.

5.0 SUMMARY

The system provided for EMR is a fully complete system which can be used to perform drop weight impact testing to EMR described procedures and specifications. The system can measure the height of the drop weight in real-time, acquire test data for 2 clip gauges and 1 tup gauge, and an accelerometer. The system can be expandable up to 8 channels in the future. A graphics software package has also been provided to provide the user with most required functions to analyze data.

The instrumentation allows the measurement of mechanical properties of metals that are to be developed for marine applications. The instrumentation can measure very high strain rates, and sample at a very high rate, making it very suitable for one shot waveforms such as that obtained in instrumented impact testing of metals.

APPENDIX A

CIRCUIT DIAGRAMS AND LAYOUTS

FIGURE A1 INTERNAL LAYOUT OF DAVIS SIGNAL CONDITIONING, TRANSDUCER INTERFACE BOX

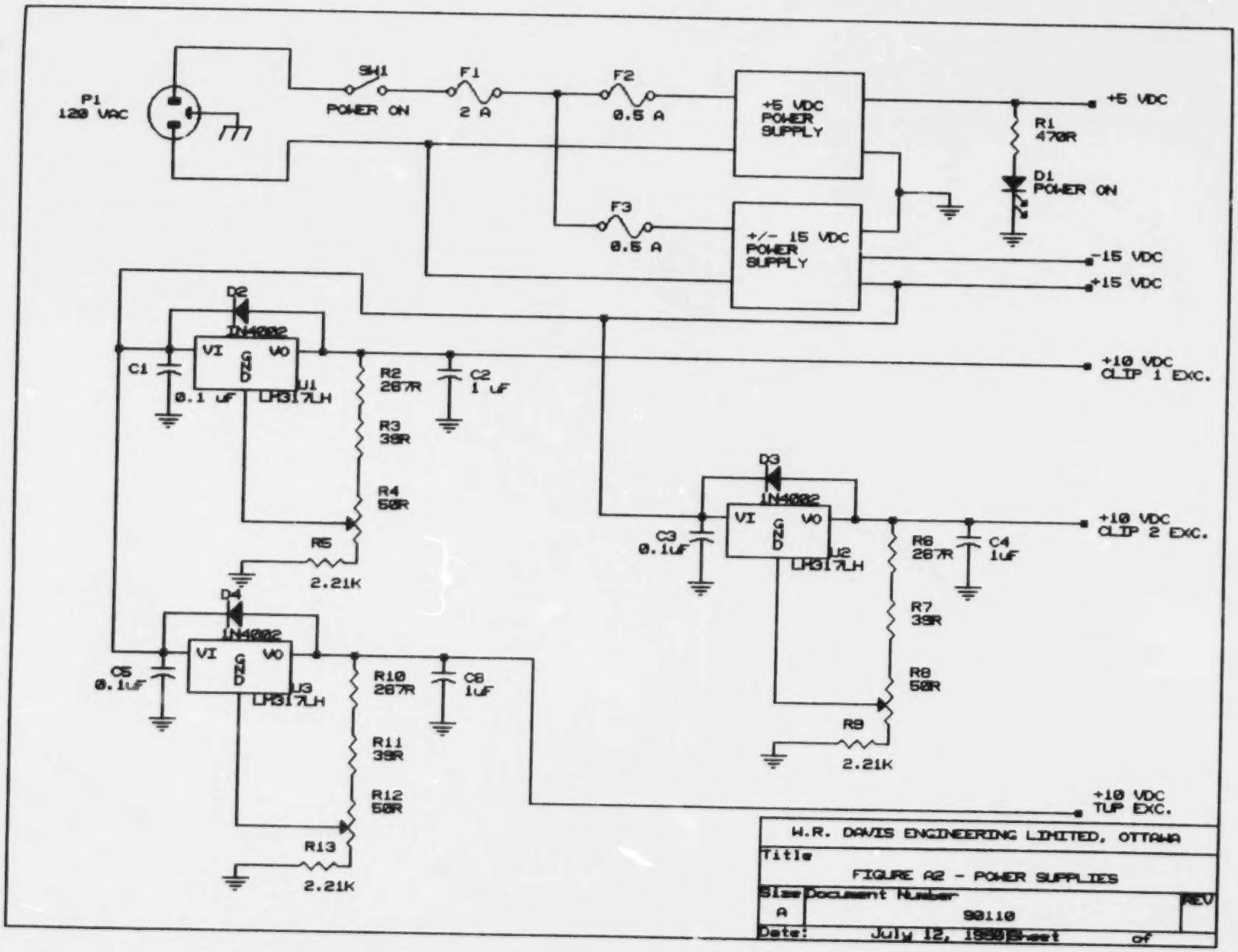
PIN DESIGNATIONS FOR FIGURE A1

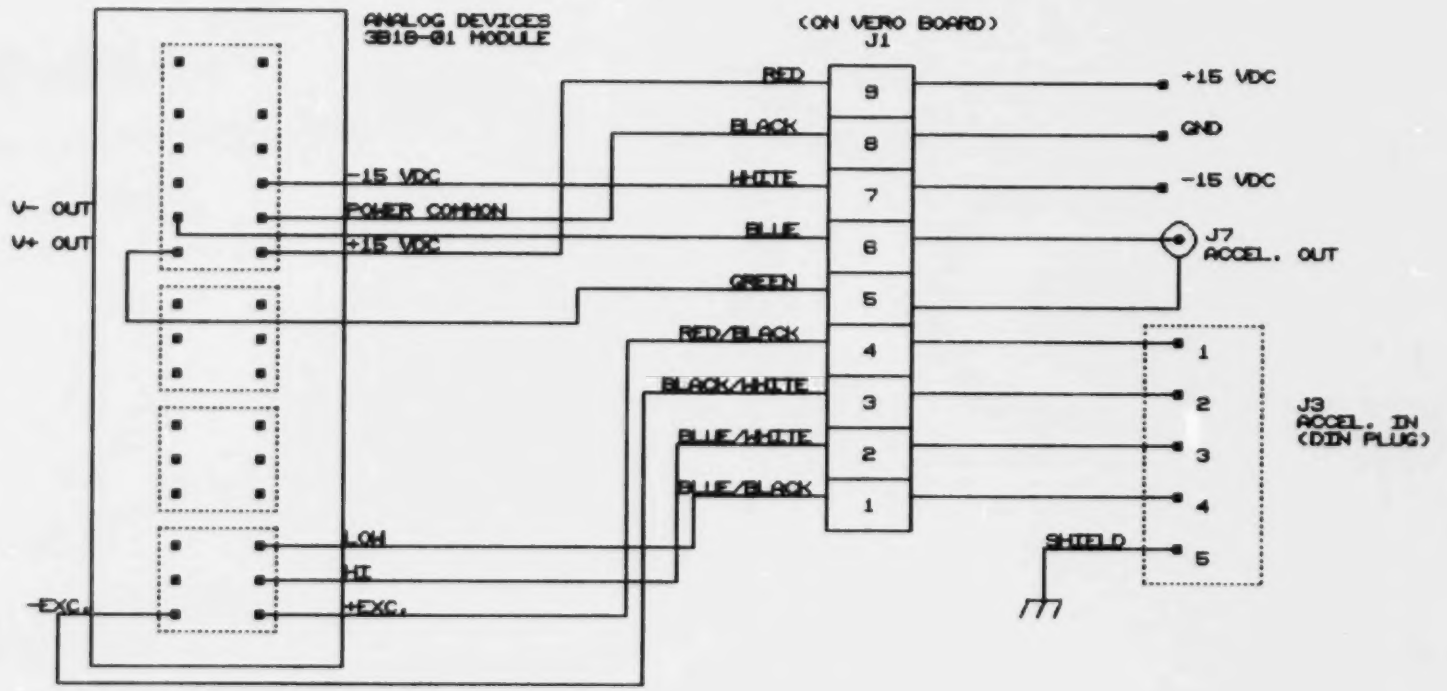
J1: Used for Analog Devices Signal Conditioner

Pin	Colour	Purpose
1	Red	+ 15 VDC
2	Black	Common
3	White	- 15 VDC
4	Blue	V+ out
5	Green	V- out
6	Red/black stripe	+ excitation
7	Black/white stripe	- excitation
8	Blue/white stripe	- high
9	Blue/black stripe	- low

J2: Used for Excitation Voltages for CLIP 1, CLIP 2, and TUP

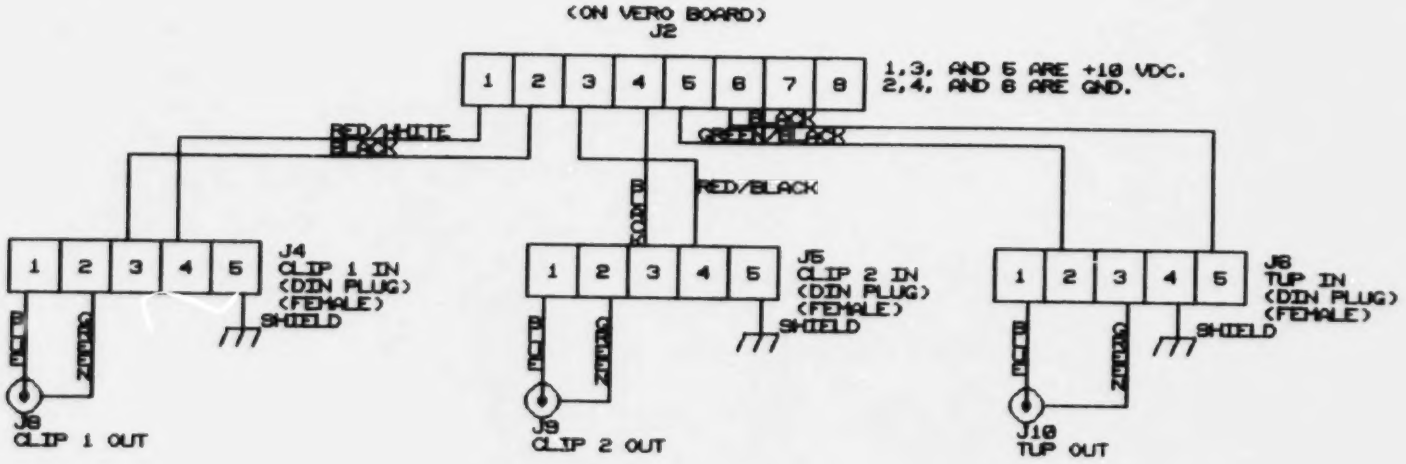
Pin	Purpose
1	+ 10 VDC excitation for CLIP 1
2	Gnd for CLIP 1
3	+ 10 VDC excitation for CLIP 2
4	Gnd for CLIP 2
5	+ 10 VDC excitation for TUP
6	Gnd for TUP
7	No connection
8	No connection


P1
120 VAC
SW1
POWER ON
F1
2 A
F2
0.5 A
+5 VDC
POWER
SUPPLY
+5 VDC
R1
470R
D1
POWER ON
F3
0.5 A
+/- 15 VDC
POWER
SUPPLY
-15 VDC
+15 VDC
D2
IN4002
VI
VO
GND
C1
0.1 uF
U1
LM317LH
R2
287R
C2
1 uF
R3
39R
R4
50R
R5
2.21K
+10 VDC
CLIP 1 EXC.
D3
IN4002
C3
0.1uF
U2
LM317LH
R6
287R
C4
1uF
R7
39R
R8
50R
R9
2.21K
+10 VDC
CLIP 2 EXC.
D4
IN4002
C5
0.1uF
U3
LM317LH
R10
287R
C6
1uF
R11
39R
R12
50R
R13
2.21K
+10 VDC
TUP EXC.
W.R. DAVIS ENGINEERING LIMITED, OTTAWA
Title
FIGURE A2 - POWER SUPPLIES
Size
A
Document Number
90110
REV
Date:
July 12, 1990
Sheet
of



NOTE: THE ANALOG DEVICES MODULE SHOWN IS THE BOTTOM VIEW OF THE MODULE.

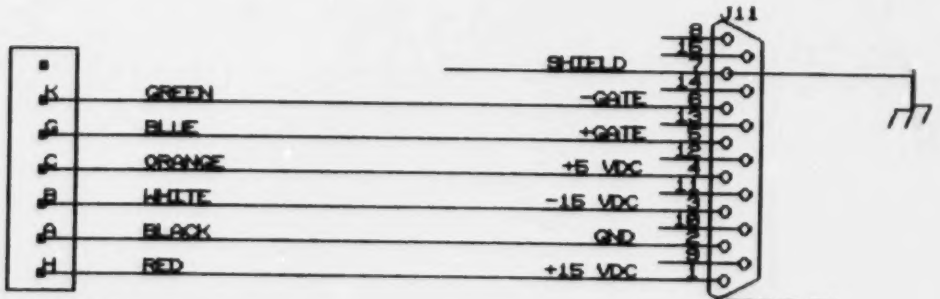
W.R. DAVIS ENGINEERING LIMITED, OTTAWA		
Title: FIGURE A3 - ACCELEROMETER SIGNAL CONDITIONER		
Size: A	Document Number: 98110	REV
Date: July 12, 1988	Sheet of	



NOTE: MATING CONNECTORS FOR J4, J5, AND J6 HAVE THE FOLLOWING WIRING CODE:

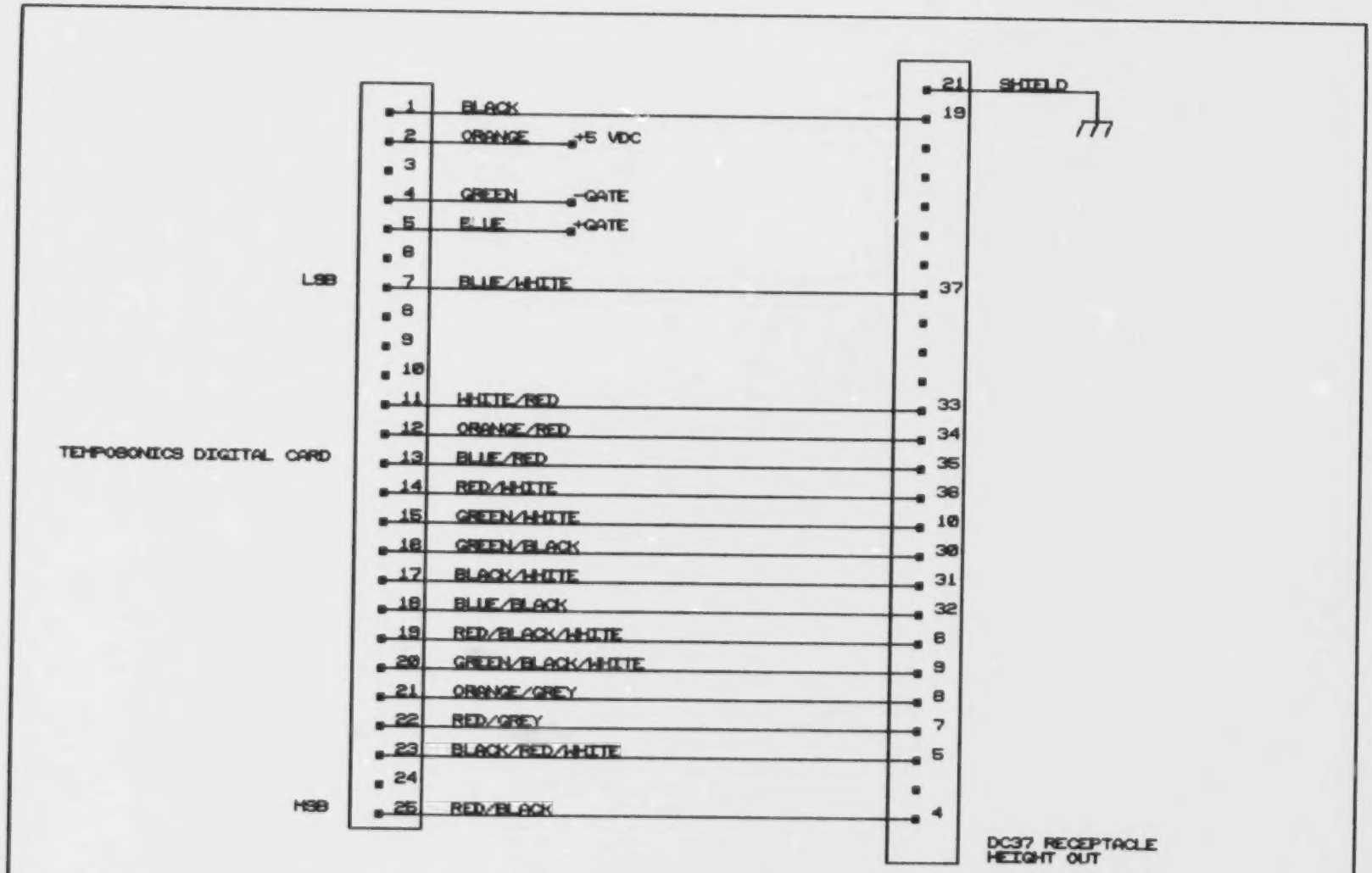
- RED +10 VDC EXC.
- BLACK GND EXC.
- WHITE +OUTPUT
- GREEN -OUTPUT

W.R. DAVIS ENGINEERING LIMITED, OTTAWA		
Title: FIGURE A4 - STRAIN GAUGE WIRING		
Size: A	Document Number: 80110	REV
Date: July 15, 1980	Sheet of	



MS CONNECTOR
CONNECTS TO TEMPOSONICS TRANSDUCER INTERFACE BOX
D,E,F, AND J ARE NOT USED

H.R. DAVIS ENGINEERING LIMITED, OTTAWA		
Title: FIGURE A6 CABLE - HEIGHT IN TO TRANS. INT. BOX		
Size: A	Document Number	REV
Date: July 16, 1988	Sheet	of



NOTE: FOR CABLE FROM HEIGHT OUT TO COMPUTER, PINS 21 AND 3 ARE SHORTED TOGETHER TO PROVIDE A HIGH TO THE MSB OF THE METRABYTE BOARD (DC37 FEMALE CONNECTOR AT COMPUTER END).

W.R. DAVIS ENGINEERING LIMITED, OTTAWA		
Title: FIGURE A6 - HEIGHT TRANS. DIGITAL CARD		
Size: A	Document Number: 90118	REV
Date: July 16, 1990	Sheet of	

APPENDIX B

MTS TEMPOSONICS BRAND LINEAR DISPLACEMENT TRANSDUCER SYSTEM - INSTALLATION AND INSTRUCTION MANUAL

MTS®

Installation and Instruction Manual

Temposonics™ Brand Linear Displacement Transducer System with Direct Digital Output

SRP control systems ltd.

5155 SPECTRUM WAY, UNIT 19
MISSISSAUGA, ONT. L4W 5A1
(416) 238-2680
FAX: (416) 238-9590

211 GORDON CRESCENT
PRINCE GEORGE, B.C. V2M 4R2
(604) 561-0622
FAX: (604) 563-4752

TOLL FREE: 1-800-268-2605

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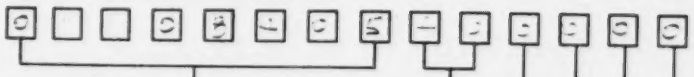
Digital Interface Box (DIB)

Model Number



TRANSDUCER
First 8 digits of transducer code

STYLE
- 40 = ± 15 Vdc and + 35°F to + 150°F - (Standard)
- 41 = ± 15 Vdc and - 40°F to 180°F
- 42 = Universal ± 15 VDC
- 43 = ± 12 Vdc and + 35°F to 150°F
- 44 = ± 12 Vdc and - 40°F to + 180°F
- 45 = Interface PCB
- 46 = Universal Interface PCB
- XX = Special

MAXIMUM UPDATE TIME MSEC
- 0 = 1.5
- 1 = 2.5
- 2 = 3.0
- 3 = 3.5
- 4 = 5.0
- 5 = 7.5
- 6 = 10.0
- 7 = 15.0
- 8 = 25.0
- X = None/Other

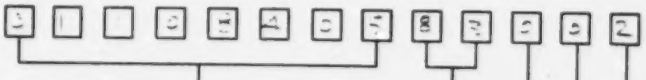
INTERROGATION
- 0 = Internal - (Standard)
- 1 = External

RECIRCULATIONS
- 0 = 1
- 1 = 2
- 2 = 4
- 3 = 8
- 4 = 16
- 5 = 32
- 6 = 64
- 7 = 128

ENVIRONMENTAL
- 0 = Standard
- 1 = Splash Resistant
- 2 = Conformal Coat

Digital Counter Card - Series 60

Model Number



TRANSDUCER
First 8 digits of transducer code

OUTPUT FORMAT
- 60 = Natural binary - 12 bits
- 61 = Natural binary - 13 bits
- 62 = Natural binary - 14 bits
- 63 = Natural binary - 15 bits
- 64 = Natural binary - 16 bits
- 65 = Natural binary - 17 bits
- 66 = Natural binary - 18 bits
- 67 = Natural binary - 19 bits (two cards required)
- 6X = Natural binary (MTS to complete code)
- 70 = BCD 3 digits (12 bits)
- 71 = BCD 3.5 digits (14 bits)
- 72 = BCD 4 digits (16 bits) (two cards required)
- 73 = BCD 4.5 digits (18 bits) (two cards required)
- 74 = BCD 5 digits (20 bits) (two cards required)
- 7X = BCD (MTS to complete code)
- XX = Other (Consult MTS Sensors Division)

ORIENTATION
- 0 = Forward count - (Standard)
- 1 = Reverse count

DATA VALIDATION
- 0 = 1 Microsecond latch pulse - (Standard)
- 1 = 12 Microsecond latch pulse
- 2 = Latch inhibit input
- X = Special (Consult MTS Sensors Division)

RESOLUTION (SCALED)
- 0 = 0.1 in. (2.5 mm)
- 1 = 0.01 in. (0.25 mm)
- 2 = 0.004 in. (0.1 mm)
- 3 = 0.002 in. (0.05 mm)
- 4 = 0.001 in. (0.025 mm)
- 5 = 0.0005 in. (0.0125 mm)
- 6 = 0.00025 in. (0.0063 mm)
- X = Other (Consult MTS Sensors Division)

Model Coding

The system components (transducer, interface box and counter card) are identified by a model coding system which identifies all construction variables required to complete your system.

The following information is provided to aid in proper wiring and operation of the system purchased. Kindly keep this information in a safe place for future reference:

SALES ORDER_____ DATE_____

SYSTEM SERIAL NUMBER (S)	RESOLUTION	RECIRCS	WIRING TABLE	CRYSTAL
1				Mhz
2				
3				
4				
5				
6				
7				
8				
9				
10				

Linear Displacement Transducer (LDT)

Model Number [ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ]

STYLE
- 01 = Standard
- 02 = Small Ruggedized head - SRH
- 03 = Flexible
- XX = Special

STROKE UNITS
- 1 = inches and tenths
- 2 = mm
- 3 = inches and eighths

STROKE LENGTH
- E.G. 0120 = 12 inches or 120 mm
- 0365 = 36 5 inches or 365 mm or 36-5/8 inches
- 1200 = 120 inches or 1200 mm

NULL/DEAD SPACE
- 5 = 5 inch D.S. and 2inch Null - (Standard for strokes up to 200 in.)
- 7 = 7 inch D.S. and 2 inch Null - (Standard for strokes over 200 in.)
- X = Special null and/or dead space

TRANSDUCER CABLE DRIVER (Analog Only)
- 0 = No. ≤ 100 ft signal cable from transducer - (Standard for all digital systems)
- 1 = Yes. > 100 ft signal cable from transducer - (Standard for intrinsically safe)

HEAD ELECTRONICS TEMPERATURE RANGE
- 1 = -40°F to +180°F (Standard for strokes greater than 12 in., positive pulse)
- 2 = -40°F to +180°F (New standard for strokes up to 12 in.)
- X = Special temp. range and/or electronics

ENVIRONMENTAL
- 0 = NEMA 1, dust tight (Standard)
- 3 = Intrinsically safe - 6 wire
- 4 = NEMA 6, hermetically sealed
- 5 = NEMA 4, splash proof (Standard with Style 02)
- X = Special

TRANSDUCER CABLE
- 0 = 5 ft with connector - analog (Style 01, 03)
- 1 = 2 ft with connector - digital (Style 01, 03, former std)
- 2 = None - analog (Style 02)
- 3 = None - digital (Style 02)
- 6 = 5 ft pigtails - analog
- 7 = 5 ft pigtails - digital
- 8 = 5 ft with connector - digital (new std.)
- 9 = Other length or connector

Digital Interface Box (DIB)

Model Number 0 1 1 0 B 4 0 5 - 3 - 5 0 0

TRANSDUCER
First 8 digits of transducer code

STYLE
40 = ± 15 Vdc and + 35°F to + 150°F - (Standard)
41 = ± 15 Vdc and - 40°F to 180°F
42 = Universal ± 15 VDC
43 = ± 12 Vdc and + 35°F to 150°F
44 = ± 12 Vdc and - 40°F to + 180°F
45 = Interface PCB
46 = Universal Interface PCB
XX = Special

MAXIMUM UPDATE TIME MSEC
0 = 1.5
1 = 2.5
2 = 3.0
3 = 3.5
4 = 5.0
5 = 7.5
6 = 10.0
7 = 15.0
8 = 25.0
X = None/Other

INTERROGATION
0 = Internal - (Standard)
1 = External

RECIRCULATIONS
0 = 1
1 = 2
2 = 4
3 = 8
4 = 16
5 = 32
6 = 64
7 = 128

ENVIRONMENTAL
0 = Standard
1 = Splash Resistant
2 = Conformal Coat

Digital Counter Card - Series 60

Model Number 5 1 1 0 B 4 0 5 8 3 0 0 2

TRANSDUCER
First 8 digits of transducer code

OUTPUT FORMAT
60 = Natural binary - 12 bits
61 = Natural binary - 13 bits
62 = Natural binary - 14 bits
63 = Natural binary - 15 bits
64 = Natural binary - 16 bits
65 = Natural binary - 17 bits
66 = Natural binary - 18 bits
67 = Natural binary - 19 bits (two cards required)
6X = Natural binary (MTS to complete code)
70 = BCD 3 digits (12 bits)
71 = BCD 3 5 digits (14 bits)
72 = BCD 4 digits (16 bits) (two cards required)
73 = BCD 4 5 digits (18 bits) (two cards required)
74 = BCD 5 digits (20 bits) (two cards required)
7X = BCD (MTS to complete code)
XX = Other (Consult MTS Sensors Division)

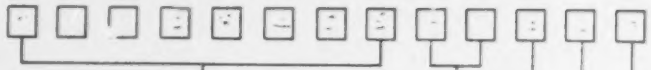
ORIENTATION
0 = Forward count - (Standard)
1 = Reverse count

DATA VALIDATION
0 = 1 Microsecond latch pulse - (Standard)
1 = 12 Microsecond latch pulse
2 = Latch inhibit input
X = Special (Consult MTS Sensors Division)

RESOLUTION (SCALED)
0 = 0.1 in (2.5 mm)
1 = 0.01 in (0.25 mm)
2 = 0.004 in (0.1 mm)
3 = 0.002 in (0.05 mm)
4 = 0.001 in (0.025 mm)
5 = 0.0005 in (0.0125 mm)
6 = 0.00025 in (0.0063 mm)
X = Other (Consult MTS Sensors Division)

Digital Counter Card - Series 80

Model Number



TRANSDUCER
First 8 digits of transducer code

OUTPUT FORMAT
- 80 = Natural binary parallel transmission (12 bits)
- 81 = Natural binary parallel transmission (13 bits)
- 82 = Natural binary parallel transmission (14 bits)
- 83 = Natural binary parallel transmission (15 bits)
- 84 = Natural binary parallel transmission (16 bits)
- 85 = Natural binary parallel transmission (17 bits)
- 86 = Natural binary parallel transmission (18 bits)
- 87 = Natural binary parallel transmission (19 bits)
- 8X = Natural binary (Ask MTS to complete code)
- 89 = Natural binary, other than above
- 90 = BCD 3 digits 12 bits (999 max reading)
- 91 = BCD 3-1/2 digits 14 bits (1999 max reading)
- 92 = BCD 4 digits 16 bits (9999 max reading)
- 93 = BCD 4-1/4 digits 17 bits (19999 max reading)
- 94 = BCD 4-1/2 digits 18 bits (39999 max reading)
- 95 = BCD 5 digits 20 bits (99999 max reading)
- 9x = BCD (Ask MTS to complete code)
- 99 = BCD, other than above

ORIENTATION
- 0 = Forward count - (Standard)
- 1 = Reverse count

DATA VALIDATION
- 0 = 1 Microsecond latch pulse and latch inhibit input (Standard)
- 1 = 12 Microsecond latch pulse and latch inhibit input
- x = Other, or special! (Consult MTS Sensors Division)

RESOLUTION (SCALED)
- 0 = 0.1 in. (2.5 mm for metric strokes)
- 1 = 0.01 in. (0.25 mm for metric strokes)
- 2 = 0.004 in. (0.1 mm for metric strokes)
- 3 = 0.002 in. (0.05 mm for metric strokes)
- 4 = 0.001 in. (0.025 mm for metric strokes)
- 5 = 0.0005 in. (0.0125 mm for metric strokes)
- 6 = 0.00025 in. (0.0063 mm for metric strokes)
- 9 = Other or unscaled (Consult MTS Sensors Division) and specify resolution separately

New Features and Design Changes

- Zero preset by DIP switches - can be reset in the field if desired
- Latch inhibit offered as standard at no charge (pin 24)
- Latch pulse now offered on pin 3 (formerly on pin 24)
- Millimeter resolution is now standard for strokes specified in millimeters
- Card width now 4-1/2 in. (formerly 4-1/4 in.)

Section I
Introduction

Product Improvements

This edition of the Installation and Instruction Manual covers both Series 60 Digital Counter Cards (the older version) and Series 80 Digital Counter Cards (released in June 1988). Before installation, you must determine which type of card you are using in your application. Use the following table to identify your card:

Type	Series 60 (former)	Series 80 (June 1988)
Width	4-1/4 in	4-1/2 in
Color	Tan	Green
Zero preset	by fixed jumpers in U5	by DIP switches S1 and S2

Both versions have the same pattern of mounting holes for surface mounting, and both are rack-mountable.

Notice also that Digital Interface Boxes shipped after March 1, 1988 are supplied with the capability for driving a transducer cable up to 100 feet long. Refer to Section 3 for cable recommendations.

The Temposonics brand Linear Displacement Measurement System measures the position of a external magnet to a high degree of precision. The system measures the time interval between an interrogation pulse and a return pulse. The interrogation pulse is transmitted to the transducer. The return pulse is created by the magnet, which is located at the position to be measured. The time difference between pulses is converted to a natural binary or BCD direct digital output signal.

The direct digital output system components include a linear displacement transducer (LDT), a digital interface box (DIB), and a digital counter card. When supplied as a scaled system, these system components are matched and factory calibrated to provide an exact, discrete resolution.

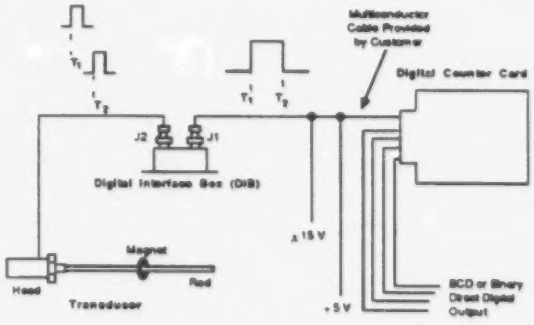


Figure 1-1. Linear Displacement Measurement System Functional Description

Temposonics normally supplies a "full digital" system, consisting of all three system components. If the counter card function is performed in a digital computer, programmable controller, or motion controller (such as the MTS Motion Plus™ TDC series controller), a "half digital" system is often supplied. The half digital system consists of the LDT and digital interface electronics only, with system variables factory set to customer specifications.

1.1 Transducer (LDT)

The interrogation pulse travels the length of the transducer by a conducting wire threaded through the hollow waveguide. The waveguide is spring loaded within the transducer rod and exhibits the physical property of magnetostriction. When the magnetic field of the interrogating pulse interracts with the stationary magnetic field of the external magnet, a torsional strain pulse or "twist" is produced in the waveguide. This strain pulse travels in both directions, away from the magnet. At the end of the rod, the strain pulse is damped within the "dead zone" (5 to 7 inches in length). At the head of the transducer, two magnetically coupled sensing coils are attached to strain sensitive tapes. The tapes translate the strain pulse through coils to an electrical "return pulse". The coil voltage is then amplified in the head electronics before it is sent back to the interface box as the conditioned "return pulse".

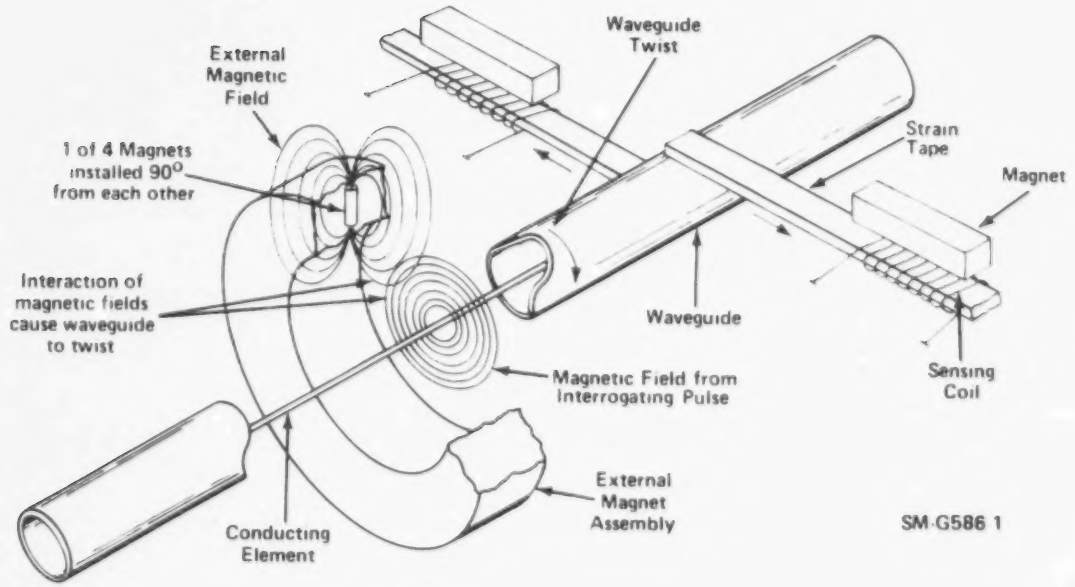


Figure 1-2. Waveguide Interaction

1.2 Digital Interface Box (DIB)

The digital interface box (DIB) (optionally available as a card) contains the intelligence for interrogation and return pulse sensing of the transducer.

The interrogation frequency is factory determined to allow sufficient time for return pulse sensing based upon the transducer stroke and optional recirculations. The frequency of interrogation is controlled by a 555 integrated circuit timer and the required R-C network for the desired time constant. Optionally, an external interrogation pulse input is provided on J-2 for user interrogation and synchronization with the selected receiver device. (Consult MTS Sensors Division for application notes.)

The interrogating pulse turns on a flip-flop, which stays on until the return pulse switches the signal off. The time "length" of the signal is directly proportional to magnet position, and after buffering within the box, the pulse is sent to the counter card as the pulse duration signal (refer to Figure 1-1).

NOTE

The pulse duration output signal is absolute and should not be confused with frequency or "pulse train" type signals, such as provided with encoders. Pulse counting techniques cannot be used.

Most digital interface boxes use a technique termed "recirculations" to improve system resolution. The recirculation number (2, 4, 8, 16, 32, etc) is factory set within the electronics to provide a pulse duration signal multiplier equal to the number of recirculations. The technique uses return pulses to trigger additional interrogation pulses. The number of "recirculation pulses" is determined at the time of order and should not be changed without factory consultation.

1.3 Digital Counter Card

The digital counter card measures the on-time of the interface box pulse duration signal. This is accomplished by using a crystal oscillator with frequency selected to provide the desired resolution (counts per inch).

The leading edge of the pulse duration signal enables the counter registers, and the trailing edge triggers a "latch pulse" to download the count into the output registers. The latch pulse is normally available for the receiver device to interpret as a "data valid" signal; normally low = **data valid**, TTL level high = **data invalid.** The latch pulse frequency is the same as the interrogation frequency, and the duration is nominally 1 microsecond. Refer to Figure 3-5.

Scaling of the counter card is accomplished by matching the counter card crystal frequency to the gradient of the transducer to provide 0.001 inch, 0.0005 inch, etc, per count. Unscaled systems may require scaling within the receiver device, depending upon desired accuracy.

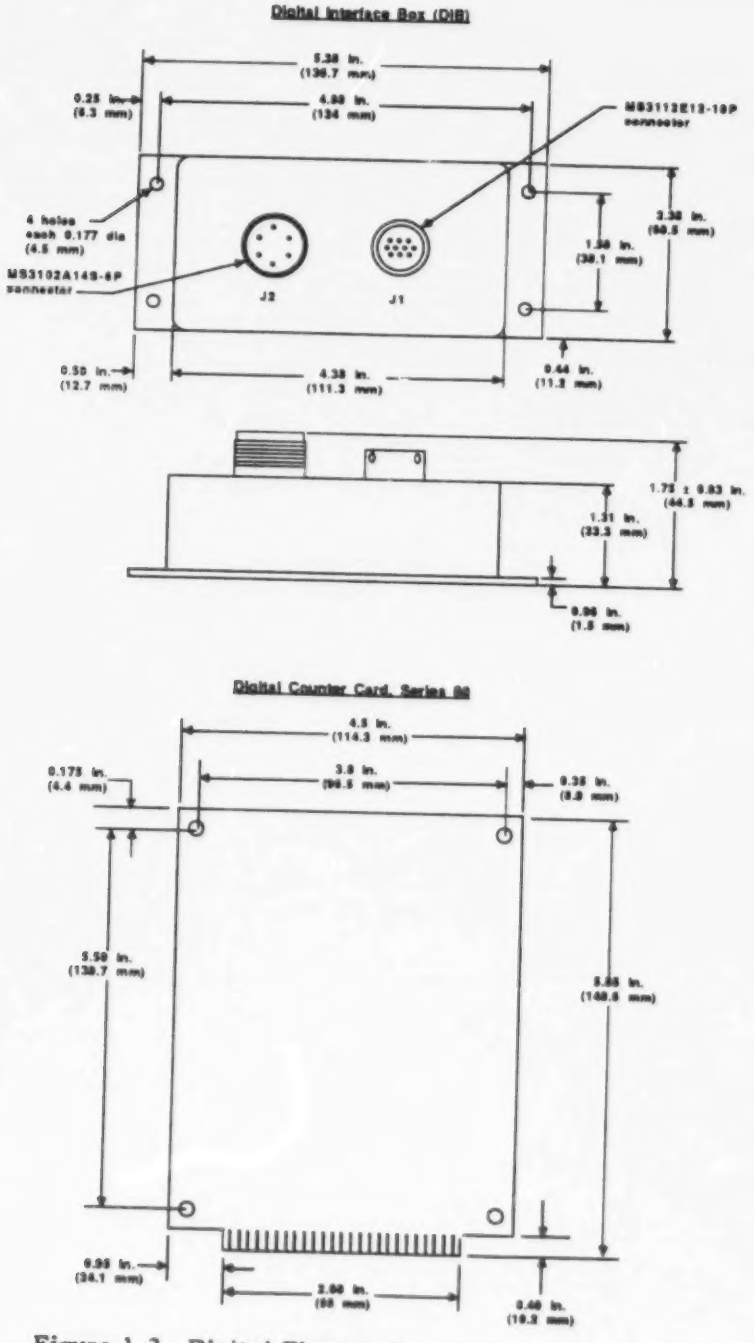


Figure 1-3. Digital Electronics

1.3.1 Scaling

In most cases, the system supplied is a scaled system. Scaling refers to the selection of system component variables so that the natural binary output represents a discrete number of inches per count, such as 0.002 inch, 0.001 inch, or 0.0005 inch per count. For BCD outputs, scaling means that the output reads directly inches (mm, etc), and need not be corrected mathematically.

The system variables that are matched include the transducer stroke, the number of recirculations, the null point, and the counter card crystal oscillator clock. The transducer, interface box and counter card are factory calibrated to provide the desired resolution. The counter card crystal frequency is calculated based upon the transducer velocity gradient, which is unique to the transducer serial number. The zero pre-set is factory set on the counter card, and is also matched to the transducer. To maintain a scaled output, the user should use a transducer and counter card with the same serial number. Substitution of interface boxes of the same stroke and recirculation number does not affect the output reading.

An unscaled system is provided upon request. An unscaled system may require calibration (refer to Subsection 3.4) to mathematically correct the digital output to read in inches, millimeters, etc. The scale factor for unscaled systems is not a discrete number of inches per count, but should be within ±0.2% of the specified resolution for 27-28 MHz systems. For example, an unscaled system specified for 0.001 inches per count may have a scale factor of 0.001002 inches per count (approximately). Similarly, an unscaled BCD output may have a scale factor of 1.002 inches per inch of reading.

Interchanging system components which do not have the same serial number will also result in an unscaled output. Refer to troubleshooting (Subsection 4.4) and Subsection 1.3.3 below.

1.3.2 "Universal" Interface Box or Card

Universal boxes (or cards) are supplied to certain customers upon request. In a universal box, the DIB interrogation pulse timing is set for a certain maximum stroke length, typically from 60 to 72 inches. The box will interrogate at the maximum stroke frequency, but can be used with any transducer with stroke length greater than 12 inches and up to the maximum. (Transducers with ≤ 12 inches are normally negative pulse interrogation and require a pulse change modification within the DIB.) The recirculation setting is also factory set, and will provide published resolution with the proper recirculation number.

The only performance change is that the update time will be that for the maximum stroke length of the interface box (refer to general bulletins). Also note that a small zero shift may occur when used with transducers of different stroke length.

1.3.3 "Universal" Counter Card

A universal counter card differs from a scaled counter card in two ways:

1. The crystal is selected based upon an "average" transducer gradient.

2. The zero pre-setting is selected using a randomly selected transducer with an "average" gradient.

The averaging results in a scale factor within ±0.6% of the specified nominal resolution. The zero position will also be affected, but should be within ±0.1 inches of the specified null position.

To correct for scale and zero offset, refer to Subsection 3.4, System Calibration.

Also note that if a randomly selected counter card is used with a transducer, the system will perform as a "universal" counter card system.

1.3.4 System Component Changes

The following general rules apply when interchanging system components or ordering spare parts:

1. Use system components with matched serial numbers whenever possible.

2. Use the crystal (Y1 or U4 on the counter card) with the transducer that is matched to it.

3. Use the zero pre-set (U5 on the counter card) with the transducer and crystal that is matched to it. (The zero pre-set is a removable 18 pin jumpered DIP socket on Series 60 cards, or two DIP switches on Series 80 cards.)

4. Whenever system components are not matched, or a non-matched crystal (or counter card) is used, a system calibration (refer to Subsection 3.4) should be performed.

5. If interface boxes are interchanged, it is preferable that they be of the same stroke and recirculation setting (refer to Subsection 1.3.2).

1.3.5 Spare Parts and Inventory Considerations

If ordering a spare transducer, a matched crystal and zero pre-set should be ordered (for Series 60 cards only) to avoid system calibration upon replacement. For Series 80 cards, the zero can be set using DIP switches.

A universal type spare interface box or counter card can be used as a common spare. However, a system calibration should be performed after any system component change.

1.3.6 Receiver Electronics without Scaling Feature

Use of the Temposonics Linear Displacement Measurement system with receiver electronics which does not permit field scaling requires special application considerations. A mechanical means of zero-positioning of the magnet must be designed into the installation, and a unit with scaled output must be used.

1.4 Specifications

Parameter	Specification
Supply Requirements	± 15 Vdc & + 5 Vdc, ± 5%, 1% ripple max. + 15 V at 100 mA – 15 V at 75 mA + 5 V at 1.2 amps (400 mA for DIB; 800 mA counter card)
Electrical Stroke	As specified. Up to 360 inch available
Null Position	Fixed, 2 inches from hex (standard), or as specified
Dead Space	Fixed, 5 or 7 inches from end of rod, as specified
Non-Linearity	± 0.05% full stroke, maximum
Repeatability	Better than ± 0.001% (0.0001 inch minimum)
Hysteresis	0.0008 inch maximum
Temperature Coefficient	0.00018 inch /°F (0.00011 inch for ≤ 12 inches stroke) + 3ppm/°F/ inch stroke - transducer. 5ppm/°F nominal for external electronics
Operating Temperature	– 40 to + 180°F transducer rod + 35 to + 150°F head electronics (≤ 12 inches)* – 40 to + 180°F head electronics (>12 inches) + 35 to + 150°F digital interface box
Output	TTL compatible, nominal 0 & 5 Vdc, parallel, true high. Source Current: 0.8 mA Sink Current: 16 mA
Operating Pressure	Rated by Factory Mutual for 3000 psi (20.68 MPa) operating pressure, and 8000 psi (55 MPa) peak pressure.
Adjustments	None

*Units shipped after 6-1-88 are suitable for – 40 to + 180°F regardless of stroke.

Specifications are subject to change without notice. Contact MTS for verification of specifications critical to your needs.

Section II
Service

2.1 General

The Temposonics Brand Linear Displacement Measurement System does not require service under normal use. The system is non-contacting, solid state, and performance does not degrade, age or drift over time.

Digital systems have a zero adjustment only. They do not have any field adjustments for scale purposes. The output is factory set during final calibration by selection of the counter card crystal frequency and zero pre-set. If a system configuration change requires a new resolution, the system must be returned to the factory to perform the changes. Alternatively, receiver device software may be reprogrammed to adjust to the new settings in some cases.

If a system performance check is desired, use the calibration procedure in Subsection 3.4.

Section III
Installation

This section describes general installation procedures for the Digital Linear Displacement Transducer measurement system. Specific installation procedures depend on the application. The installation involves environmental considerations, mechanical installation and electronic connections.

3.1 Environmental Considerations

The location of components is determined by the application requirements. The following describe the environments suitable for the component configuration. Ensure the components can withstand the environment where they will be installed.

- A transducer assembly with a blue dust cover over the LDT head is suitable for general purpose applications located indoors.
- A transducer assembly with a ruggedized LDT head cover is suitable for environments exposed to moisture, vibration and outdoor elements.
- The digital interface box must be protected from moisture and vibration.
- The digital counter card is suitable for non-hazardous, environmentally-controlled atmospheres only, such as control rooms or control panels indoors.
- A transducer assembly with the intrinsically safe design (approved for Class I, Division 1, Groups C and D) is available for hazardous areas.

NOTE

The **intrinsically safe** design has special installation requirements which are not covered in this manual. Consult MTS Sensors Division for details.

3.2.1 Mechanical Installation

The mechanical installation includes mounting the transducer, the counter card, electronics box and the permanent magnet. Before installing the transducer assembly, it is necessary to know the null position, stroke length, full-scale position and the dead zone (refer to Figure 3-1).

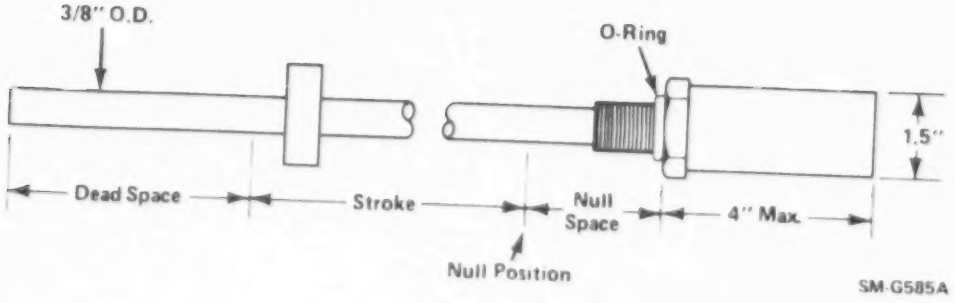


Figure 3-1. LDT Assembly

Take the following steps to install the LDT measurement system:

1. The transducer assembly is mounted to the selected location using the 3/4 inches (19 mm), 16 UNF thread of the transducer. Allow sufficient area to access the hex head to tighten the transducer assembly. Install an O-ring (type MS28778-8 is recommended) in the special groove if a pressure or moisture seal is required.

2. Install the permanent magnet over the LDT rod. The permanent magnet is mounted to the movable device from which displacement is to be measured. To minimize the effect of ferromagnetic materials (such as iron, nickel, steel, etc) on the magnetic field of the permanent magnet, ensure the minimum spacing requirements are met as shown in Figure 3-2. Any non-magnetic materials can be in direct contact with the permanent magnet. Types of magnets are shown in Figure 3-3.

NOTE

Clearance between the magnet and the LDT rod is not critical. However, contact between the components will cause wear over time. The installation of supports or readjustment of the supports is recommended if the magnet contacts the LDT rod.

3. Move the permanent magnet full-scale to determine if support brackets are required. If the magnet contacts the LDT, mount a support bracket to the end of the LDT. Long transducers may need additional supports to be attached to the transducer rod. Refer to Subsection 3.2.2 for the procedure for installing transducer supports.

4. Mount the digital interface box in a location within reach of the LDT assembly cable. Older systems allow the digital interface box to be mounted within 2 feet of the LDT assembly; systems supplied after 3-1-88, within 100 feet.

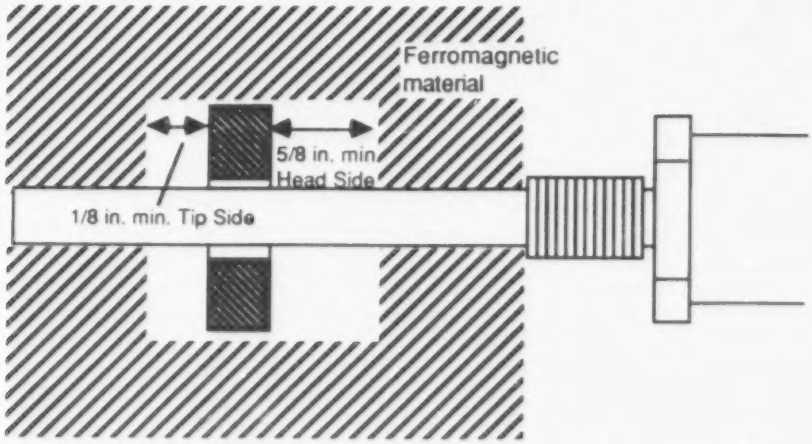


Figure 3-2. Ferromagnetic Material Mounting Specifications

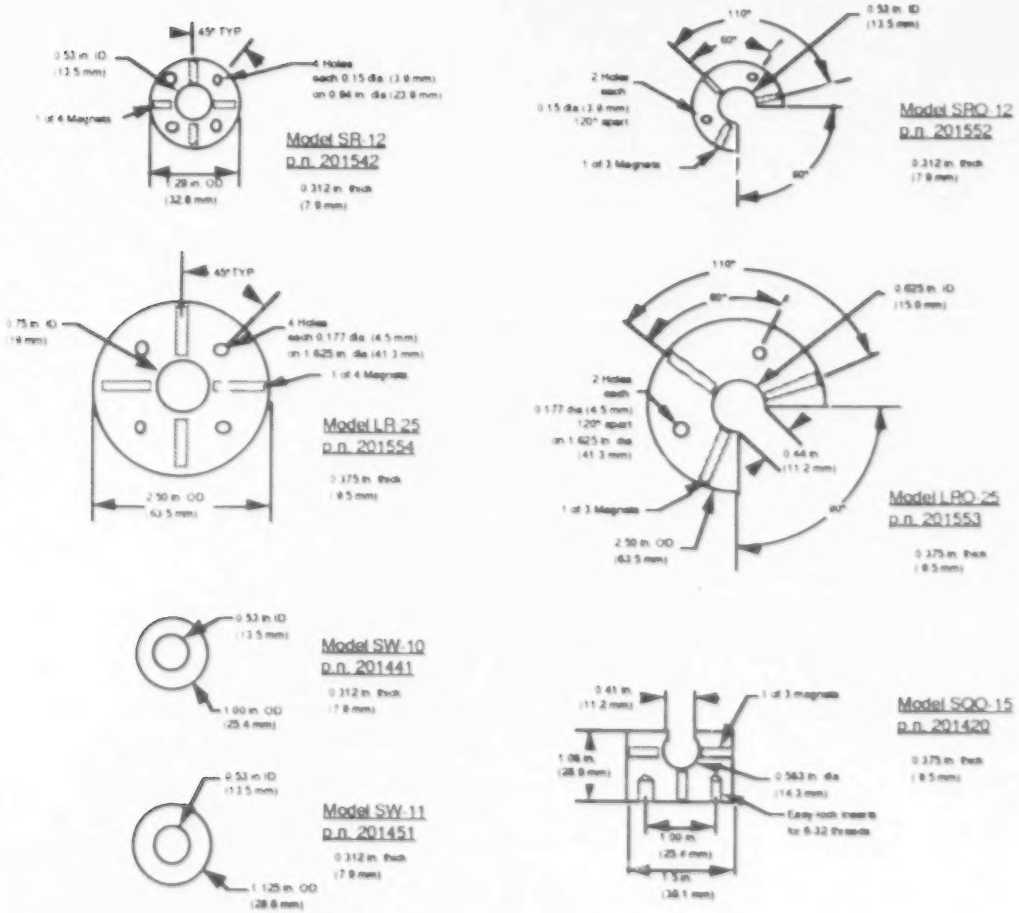


Figure 3-3. Types of Magnets

6. Mount the digital counter card within 300 feet* of the interface box. The card may be mounted in a standard card cage, or can be surface mounted using standoffs. Allow at least one inch on each side of the counter card for proper spacing. It is best to mount the card so that the edge connector is accessible for signal level testing.

NOTE

The counter is matched to the transducer by serial number. Do not interchange counter cards (refer to System Component Matching).

*Consult MTS Sensors Division for longer distances.

3.2.2 Types of Transducer Supports

Long transducers (more than 4 feet long) may require supports to maintain proper alignment between the transducer rod and the permanent magnet. All flexible transducers require supports to maintain the design shape. When transducer rod supports are used, special permanent magnets are required.

Transducer supports attached to the active stroke length must be made of non-ferrous material with a gage thickness which will permit the permanent magnet to pass without obstruction. Transducer supports connected to the dead zone can be any type of material since the permanent magnet should not enter that area. The following are descriptions of several types of transducer supports.

Loop Type Support

Loop type supports are recommended for straight transducers and are also used with channel supports. Loop type supports must be thin enough to permit free movement of the magnet. Figure 3-5 illustrates the fabrication of a loop type support. Figure 3-6 illustrates a typical channel support.

NOTE

When open magnets are used, ensure the transducer rod remains within the inside diameter of the magnet throughout the length of the stroke. If the transducer rod is allowed to leave this zone and enter the cut-out area of an open magnet, the transducer signal will be lost. Figure 3-4 shows correct and incorrect transducer rod positions.

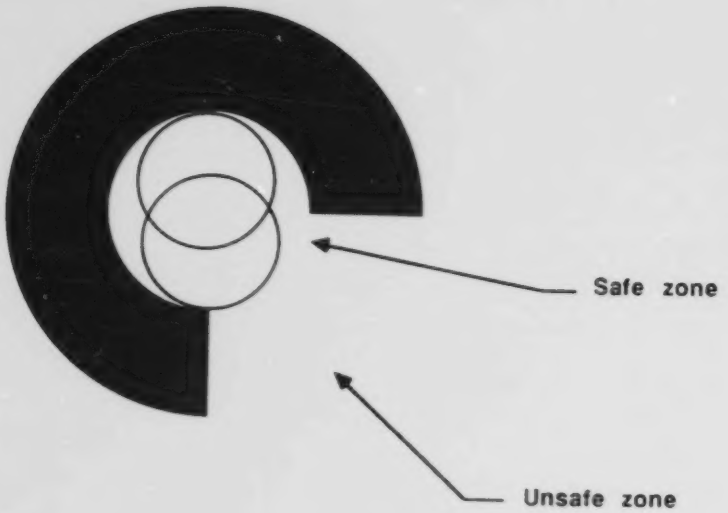


Figure 3-4. Transducer Rod Positions within an Open Magnet

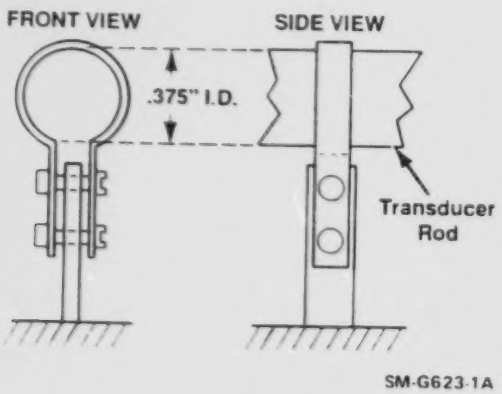


Figure 3-5. Loop Support

Channel Type Support

Channel type supports are typically straight. Loop supports are normally required to keep the transducer within the channel. Figure 3-6 illustrates the channel support. Channel supports are available from various manufacturers ("linear ways") or may be fabricated.

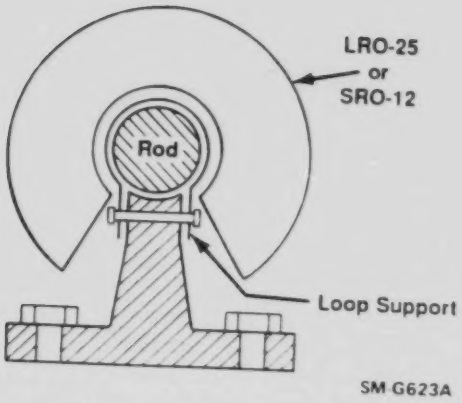


Figure 3-6. Channel Support

Guide Pipe Supports

Guide pipe supports are sections of thin-walled pipe, normally used to support flexible transducers. A guide pipe support is constructed of non-ferrous material to maintain the desired shape. The transducer rod is installed into the pipe, therefore, the inside diameter of the pipe must allow proper clearance to install the rod and the outside diameter must allow for magnet clearance. Refer to the pipe manufacturer's specifications and dimensions (schedule 10, 40, etc) to select pipe in accordance with transducer and magnet specifications and dimensions. Guide pipe is typically supported at each end of the pipe. Figure 3-7 illustrates a guide pipe support.

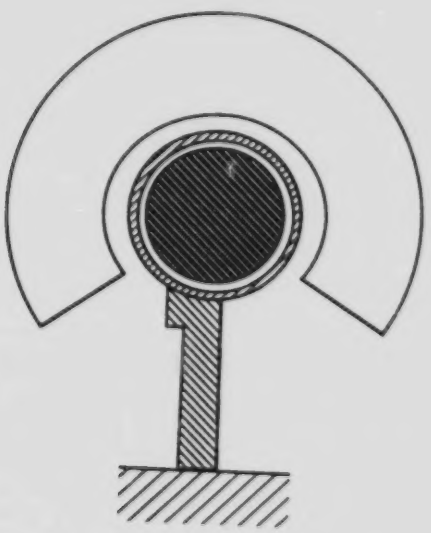


Figure 3-7. Guide Pipe Support

Spring Loading or Tensioning

The transducer rod (flexible or rigid) can be spring loaded or tensioned using a stationary weight. Attach a spring mechanism or weight to the dead zone of the transducer rod with a clamping device which will not deform the transducer rod. The maximum weight or spring tension is 5 to 7 lbs. Spring loading or tensioning is recommended for installations that do not permit loop type supports and are subject to vibration or abuse.

3.2.3 Flexible Transducer Installation

This subsection provides the installation procedure for flexible transducers. It is necessary to know the null position, stroke length, full-scale position and the dead zone to install the transducer (refer to Figure 3-1). Before installing the flexible transducer, review the following considerations:

- All flexible transducers are custom manufactured for a specific application and installation. The specific requirements are determined prior to ordering, which includes specific curvatures and straight sections at specific distances from the transducer head.
- Flexible transducers should not be subjected to temperatures above 130°F (54°C) unless specified. The temperature of the transducer rod should not vary more than ±30°F (±16°C) unless specified.
- Flexible transducers should not be subjected to pressures above atmospheric pressure.
- Flexible transducers can be flexed or curved to a minimum diameter of 36 in. (91 cm) during installation.
- Flexible transducers require supports or anchoring to maintain the designed shape. Refer to Subsection 3.2.2 for information to install transducer supports.
- Some long transducers are ordered as flexible units to facilitate shipping and handling only, even though they are used for straight applications.

CAUTION

DO NOT attempt to install a flexible transducer without knowledge of the design installation dimensions. Failure to follow the design dimensions can result in improper operation or transducer damage.

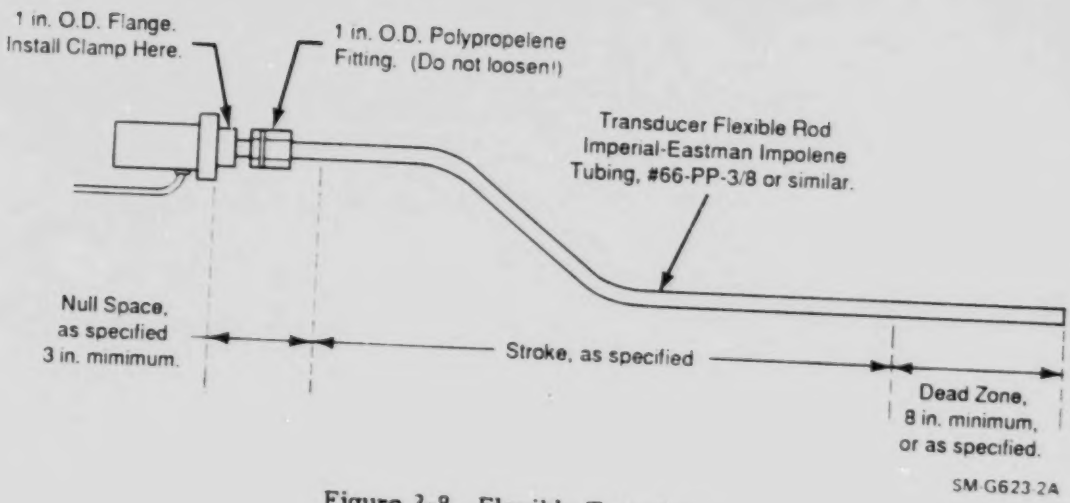


Figure 3-8. Flexible Transducer

Take the following steps to install a flexible transducer:

CAUTION

DO NOT loosen or mount the transducer using the polypropylene fitting near the transducer head. This will cause damage to the transducer.

1. Transducers supplied with a 1 inch O. D. head flange require a U-bolt, flange collar or similar clamping device to keep the transducer head stationary.

   Transducers with a threaded hex can be mounted using the threads. If the transducer must be rotated to engage the threads, ensure the flexible rod can rotate freely. If the rod binds or cannot be rotated, a bracket or threaded flange should be used (hold the transducer stationary and rotate the bracket or flange to engage the threads).

2. Install the permanent magnet over the LDT rod. The permanent magnet is mounted to the movable device from which displacement is to be measured. To minimize the effect of magnetic materials on the magnetic field of the permanent magnet, ensure the minimum spacing requirements are met as shown in Figure 3-2. Only nonmagnetic materials can be in direct contact with the permanent magnet.

3. Mount the digital interface box in a location within reach of the LDT cable. Older systems allow the box to be mounted within 2 feet of the LDT assembly. Newer systems with buffer driver allow the interface box to be mounted within 100 feet of the LDT assembly. All units after 3-1-88 have this driver.

4. Refer to Subsection 3.2.2 for information to install transducer supports.

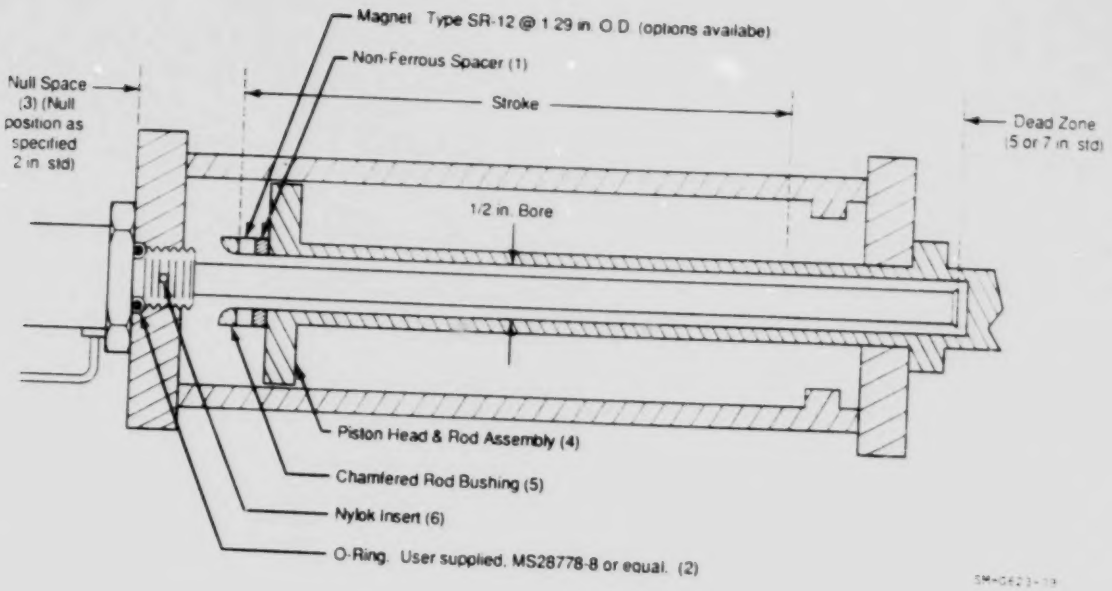

Magnet Type SR-12 @ 1.29 in O.D. (options available)
Non-Ferrous Spacer (1)
Null Space (3) (Null position as specified 2 in. std)
Stroke
Dead Zone (5 or 7 in. std)
1/2 in. Bore
Piston Head & Rod Assembly (4)
Chamfered Rod Bushing (5)
Nylok Insert (6)
O-Ring. User supplied. MS28778-8 or equal. (2)

Figure 3-9. Typical Cylinder Installation, Piston at Full Retraction

3.2.4 Cylinder Installation

This subsection provides information for cylinder applications. The rigid transducer installation procedure can be used as a guide for cylinder installations. Figure 3-9 shows a typical cylinder installation. Review the following before attempting a cylinder installation.

1. Use a non-ferrous (plastic, brass, teflon, etc) spacer to provide 1/8 inch (32 mm) minimum space between the magnet and the piston.

2. An O-ring groove is provided at the base of the transducer hex head for pressure sealing. Temposonics uses MIL-standard MS33514 for the O-ring groove. Refer to MIL-standard MS33649, (or SAE J514) for machining of mating surfaces. Use O-ring number MS28778-8 or equal.

3. The null space is customer specified at full retraction according to the installation design and cylinder dimensions. Ensure the magnet can be mounted at the proper null position.

4. The piston head shown in Figure 3-9 is typical. For some installations, depending on the clearances, it may be desired to countersink the magnet.

5. A chamfered rod bushing should be considered for strokes over 5 feet (1.5 meters) to prevent wear on the magnet as the piston retracts. The bushing should be made from teflon or similar material.

6. A nylok self locking insert is provided on the transducer threads. An O-ring groove is provided at the base of the transducer hex head for pressure sealing.

7. The recommended bore for the cylinder rod is 1/2 inch (13 mm). The transducer rod includes a 0.44 inch (12 mm) end plug; a flush end plug is available. Use standard industry practices for machining and mounting of all components. Consult the cylinder manufacturer for applicable SAE or MIL-specs.

CAUTION

DO NOT attempt to loosen the end plug on the transducer. If this plug is loosened or removed, reseal it with Loctite and torque the plug until it is properly seated against the end of the pipe.

3.3 Electronic Connections - General

Electronic connections are made at connectors J2 and J1 of the interface box (DIB) and at pins 1 to 25 of the counter card edge connector.

To ensure system performance to published specifications, wiring procedures and selection rules must be carefully followed.

The following recommendations are supplied for "full digital" systems, which include a Temposonics brand digital counter card. For systems which use a digital counting device in the receiver computer (such as MTS Motion Plus control systems), the counter card is not supplied. Use the following procedures in conjunction with the receiver device manufacturer's recommendations.

3.3.1 Transducer Connections

The LDT is supplied with 5 feet (standard) of integral cable. Ruggedized head designs are supplied with an extension cable. It is recommended to keep the transducer cable as short as possible to avoid possible noise or temperature effects on accuracy.

If an extension cable is required, the following guidelines must be followed:

NEMA 1 (blue cover) transducers

If supplied with 2 feet of integral cable (systems prior to 3-1-88), then, unless extension cable is specified, the digital interface box has not been modified to buffer pulse transmissions. Do not attempt to extend the cable without factory modifications to the interface box.

If supplied with 5 feet or more of integral cable (systems after 3-1-88), the interface box has been modified for pulse buffering, and extension cable can be used as described below.

NEMA 4 and 6 Ruggedized Transducers

All ruggedized transducers require an extension cable with mating connection, supplied by MTS Sensors or by the buyer. If the factory-supplied cable is 5 feet or longer, the interface box has been modified for 100 foot drive capability, and you may use a cable up to 100 feet long.

If the cable supplied is less than 5 feet long, do not attempt to extend the cable further.

Extension Cable

The extension cable is fabricated from Belden number 9931, 9730, or optionally, Belden 83506 teflon covered cable. Substitutes are not acceptable.

The maximum cable length is 100 feet. Construct the extension cable using the color codes shown in Table 3-1, or order from MTS Sensors Division.

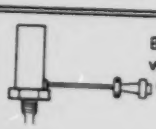
Table 3-1. J2 Connections

J2 Signal/Function	J2 Pin	Wire Color Code	
		Integral Cable or Belden 9931 83506 Extension Cables	Belden 9730 wire/shield
+ 12 to + 14.5 Vdc	A	Green	Black/Blue
DC Common/Ground	B	Black	Black/Red
Return pulse from transducer	C	Brown or Orange	Green/Blue
− 13.5 to − 14.5 Vdc	D	Blue	Black/Green
Interrogation pulse to transducer	E	White	White/Green
11.5 to + 12 Vdc	F	Red	Red/Red
Cable Ground*	-	SHIELD − see below	SHIELD − see below

* Cable Grounds:

1. Cable shields are grounded at one end of cable only.
2. Integral cable shield is connected to circuit ground within transducer head.
3. Extension cable shield should be connected to ground at the electronics box connector only. Apply ground by separate connection to earth ground or by connecting to pin B on the connector which mates to the box.

Table 3-2. J2 Mating Connectors

Transducer Head Connector	Transducer Head Design	Mating Connectors	
		To Transducer Head	To Interface Box
MS 3106A-14S-6S MS 3106E-14S-6S (environmental)	 Blue Cover w/integral cable (NEMA 1)	MS 3101A-14S-6P MS 3101E-14S-6P (environmental)	MS 3106A-14S-6S MS 3106E-14S-6S (environmental)
MS 3113H-10-6P (DT1H-10-6PN)	SRH/Hermetically Sealed (NEMA 6)	MS 3116F10-6S (environmental)	MS 3106A-14S-6S MS 3106E-14S-6S (environmental)
MS 3102E-14S-6P	SRH/Environmental (NEMA 4)	MS 3106E-14S6S (environmental)	MS3106A-14S-6S MS 3106B-14S-6S (environmental)
MS 3100F-14S-6P	Ruggedized/ Environmental (Woodit)	MS 3106E-14S-6S (environmental)	MS 3106A-14S-6S MS 3106E-14S-6S (environmental)
MS 3113H-10-6P (DT1H-10-6PN)	Ruggedized/ Hermetically Sealed (Woodit)	MS 3116F10-6S (environmental)	MS 3106A-14S-6S MS 3106E-14S-6S (environmental)

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3.3.2 Digital Interface Box Connections

Figure 3-10 shows the digital interface box connections for J1 to the power supply and receiver device.

Cables should be selected according to the following guidelines, depending upon the overall cable length between the box and counter card.

1. Cable length up to 50 feet: a twisted shielded pair is recommended for the gate signals and interrogation signals (optional). Power signals can be routed using any properly sized multiconductor cable. For areas not subject to electrical noise, a high quality shielded multiconductor cable can be used for all signals, including power.

2. Cable length between 50 and 300 feet: Use a high quality 100 ohm twin axial cable such as Belden 8227 for the positive and negative pulse duration "gate" signals. The power supply wires are routed through an additional multiconductor cable, selected and sized according to industry standards. Wire gage for dc power to the interface box should be selected to ensure minimum possible voltage drop.

3.3.3 Digital Counter Card Connections

Tables 3-3, 3-4, and 3-5 show the counter card output connection tables. In order to select the proper table, the following order variables must be known.

A)	Stroke	_____inches (mm)
B)	Resolution	_____inches (mm)
C)	Recirculations	_____=N
D)	Output format	_____BCD___natural binary
E)	Optional inputs/ outputs	_____latch inhibit (input)

The counter card divider, if supplied, is determined knowing A, B, and C, and is obvious from the table description.

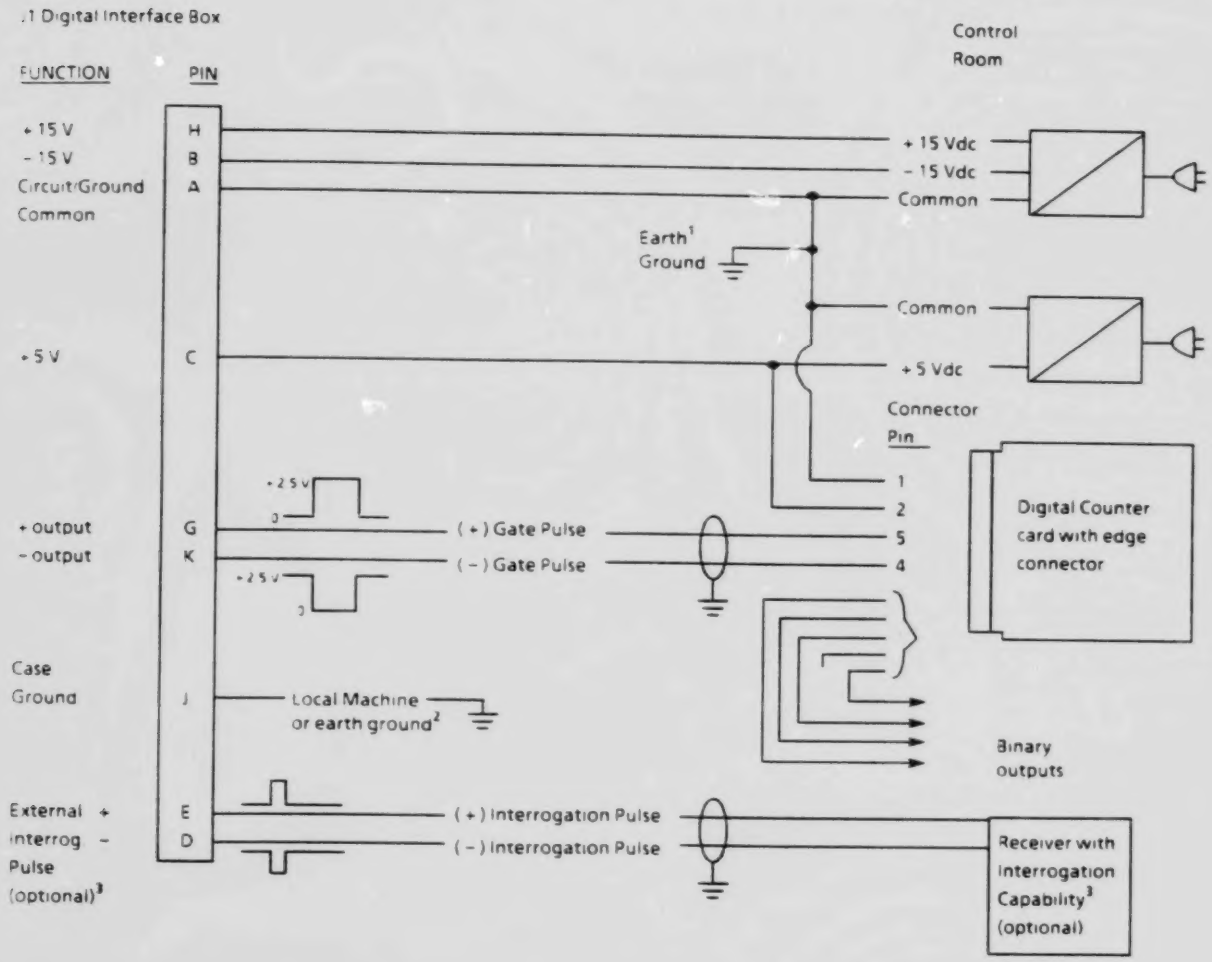
Series 60 Counter Cards

Refer to Figure 3-10 for power input (+5 Vdc) and interface box gate signal connections.

Pin 24 on the counter card is normally connected to the latch pulse (output), and is normally low; high during update of output.

Optionally, a latch inhibit (input) is supplied on pin 24. By applying a ground (sink) to pin 24, the updating of the binary output is frozen and the output does not change.

Series 80 Counter Cards (available 6/88)
Latch inhibit input is now standard on pin 24 for all Series 80 counter cards. No connection or TTL high allows updating to continue.



[1] It is common practice to apply earth ground to power supply common terminals near power supply
[2] Case ground is normally applied by installation of box to machine or local equipment
[3] Must be specified with order

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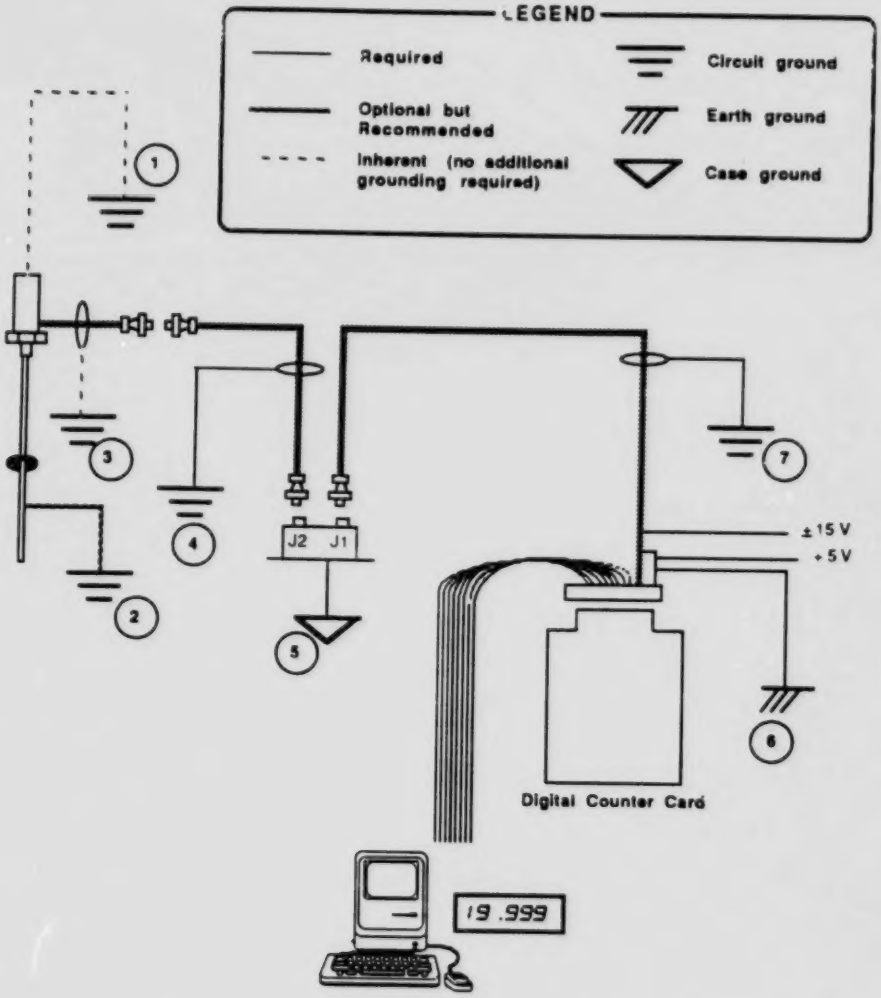
Figure 3-10. Signal and Power Wiring, Digital Systems

Table 3-3. J1 Connections

J1 Signal/Function	J1 Pin
dc Common	A
– 15 Vdc Power	B
+ 5 Vdc Power	C
External Interrogation Pulse – (Optional)	D
External Interrogation Pulse + (Optional)	E
+ Gate Output	G
+ 15 Vdc Power	H
Case Ground	J
– Gate Output	K



1. Blue dust cover (NEMA 1) is at circuit ground. Do not apply additional ground. Stainless steel or aluminum ruggedized head cover (NEMA 4, NEMA 6) is at same potential as transducer rod.

2. It is good practice to apply a machine, local, or earth ground to the transducer rod.

3. Transducers with integral cable have circuit ground applied to the cable shield. The ground does not pass through the connector to the extension cable or digital interface box.

4. Connect extension cable shield to circuit ground or local earth ground.

5. Digital interface box case is floating with respect to all grounds. It is good practice apply a local, earth or machine ground to this case.

6. Circuit or "reference" ground is established by connecting the power supply common(s) to earth ground. Do not apply additional grounds to circuit ground (at the transducer head, integral cable shield, or digital box output cable).

7. Digital interface box outputs should be shielded and grounded.

Figure 3-11. Required and Recommended Grounding

Table 3-4 is based upon a counter card with [÷1] divider (factory set). A single card is capable of 18 bits natural binary output maximum.

For the 27-28 MHz crystal, the resulting resolution and recirculations vs stroke are as follows:

1. For 0.000125 inches, N=32 recirculations, stroke up to 32 inches.
2. For 0.00025 inches, N=16 recirculations, stroke up to 65 inches.
3. For 0.0005 inches, N=8 recirculations, stroke up to 131 inches.
4. For 0.001 inches, N=4 recirculations, stroke up to 262 inches.
5. For 0.002 inches, N=2 recirculations, stroke up to 524 inches.
6. For 0.004 inches, N=1 recirculations.

Table 3-4. Counter Card Output (÷1)

Pin	Bit Weight	Decimal Value	Bit	Maximum Counts vs Number of bits*
10	LSB		2^0	1 = 1 bit
9			2^1	3 = 2 bit
8			2^2	7 = 3 bit
7			2^3	15 = 4 bit
14			2^4	31 = 5 bit
13			2^5	63 = 6 bit
12			2^6	127 = 7 bit
11			2^7	255 = 8 bit
18			2^8	511 = 9 bit
17			2^9	1023 = 10 bit
16			2^{10}	2047 = 11 bit
15			2^{11}	4095 = 12 bit
20			2^{12}	8191 = 13 bit
21			2^{13}	16,383 = 14 bit
22			2^{14}	32,767 = 15 bit
19			2^{15}	65,535 = 16 bit
23			2^{16}	131,071 = 17 bit
25	MSB*		2^{17}	262,143 = 18 bit

* MSB determined by dividing stroke by resolution and comparing to maximum counts. For example, 25 inches/0.001 = 25,000. This requires a maximum count of 32,767, yielding an MSB at pin 22.

Table 3-5 is based upon a counter card with [÷2] divider (factory set). A single card is capable of 17 bits natural binary output maximum.

For the 27-28 MHz crystal, the resulting resolution and recirculations vs stroke are as follows:

1. For 0.000125 inches, N=64 recirculations, stroke up to 16 inches.
2. For 0.00025 inches, N=32 recirculations, stroke up to 32 inches.
3. For 0.0005 inches, N=16 recirculations, stroke up to 65 inches.
4. For 0.001 inches, N=8 recirculations, stroke up to 131 inches.
5. For 0.002 inches, N=4 recirculations, stroke up to 262 inches.
6. For 0.004 inches, N=2 recirculations, stroke up to 524 inches.
7. For 0.008 inches, N=1 (or none) recirculations.

Table 3-5. Counter Card Output (÷2)

Pin	Bit Weight	Decimal Value	Bit	Maximum Counts vs Number of bits*
9	LSB		2^0	1 = 1 bit
8			2^1	3 = 2 bit
7			2^2	7 = 3 bit
14			2^3	15 = 4 bit
13			2^4	31 = 5 bit
12			2^5	63 = 6 bit
11			2^6	127 = 7 bit
18			2^7	255 = 8 bit
17			2^8	511 = 9 bit
16			2^9	1023 = 10 bit
15			2^{10}	2047 = 11 bit
20			2^{11}	4095 = 12 bit
21			2^{12}	8191 = 13 bit
22			2^{13}	16,383 = 14 bit
19			2^{14}	32,767 = 15 bit
23			2^{15}	65,535 = 16 bit
25	MSB*		2^{16}	131,071 = 17 bit

* MSB determined by dividing stroke by resolution and comparing to maximum counts. For example, 25 inches/0.001 = 25,000. This requires a maximum count of 32,767, yielding an MSB at pin 19.

Table 3-6 is based upon a counter card with [÷4] divider (factory set). A single card is capable of 16 bits natural binary output maximum.

For the 27-28 MHz crystal, the resulting resolution and recirculations vs stroke are as follows:

1. For 0.000125 inches, N=125 recirculations, stroke up to 8 inches.
2. For 0.00025 inches, N=64 recirculations, stroke up to 16 inches.
3. For 0.0005 inches, N=32 recirculations, stroke up to 32 inches.
4. For 0.001 inches, N=16 recirculations, stroke up to 65 inches.
5. For 0.002 inches, N=8 recirculations, stroke up to 131 inches.
6. For 0.004 inches, N=4 recirculations, stroke up to 262 inches.
7. For 0.008 inches, N=2 recirculations, stroke up to 524 inches.
8. For 0.016 inches, N=1 (or none) recirculations.

Table 3-6. Counter Card Output (÷4)

Pin	Bit Weight	Decimal Value	Bit	Maximum Counts vs Number of bits*
8	LSB		2^0	1 = 1 bit
7			2^1	3 = 2 bit
14			2^2	7 = 3 bit
13			2^3	15 = 4 bit
12			2^4	31 = 5 bit
11			2^5	63 = 6 bit
18			2^6	127 = 7 bit
17			2^7	255 = 8 bit
16			2^8	511 = 9 bit
15			2^9	1023 = 10 bit
20			2^{10}	2047 = 11 bit
21			2^{11}	4095 = 12 bit
22			2^{12}	8191 = 13 bit
19			2^{13}	16,383 = 14 bit
23			2^{14}	32,767 = 15 bit
25	MSB*		2^{15}	65,535 = 16 bit

* MSB determined by dividing stroke by resolution and comparing to maximum counts. For example, 25 inches/0.001 = 25,000. This requires a maximum count of 32,767, yielding an MSB at pin 15

When ordered as BCD, the counter card provides a BCD output. BCD code is a binary method of representing decimal numbers. The BCD code for a decimal number is a string of four-bit binary numbers, each of which represents one decimal digit. Only the following binary groups are used:

Decimal	Binary	Decimal	Binary
0	0000	5	0101
1	0001	6	0110
2	0010	7	0111
3	0011	8	1000
4	0100	9	1001

For example, the decimal number 8.74 is encoded in BCD as a 12-bit binary number:

8	.	7 4	=	8.74
1000	.	0111 0100	=	1000.01110100

In many cases, the BCD code for a stroke length yields a range of BCD numbers where some bits never change value. For example, 19.999 inches is represented in BCD by the 20-bit number

00011001.100110011001

Notice that, for all values from 0 up to 19.999, the first three bits will likewise be zero. This means that the remaining 17 bits are sufficient to encode a stroke of 19.999 inches; that is, one 18-bit counter card is sufficient.

Table 3-7 lists the maximum stroke length versus number of significant bits for a resolution of 0.001 inch.

Table 3-7. BCD Representations of Stroke

X (maximum stroke length in inches)	BCD Value of X	Required Number of Bits
7.999 (or 8)	0111.1001 1001 1001	15
9.999 (10)	1001.1001 1001 1001	16
19.999 (20)	0001 1001.1001 1001 1001	17
39.999 (40)	0011 1001.1001 1001 1001	18*
79.999 (80)	0111 1001.1001 1001 1001	19*
99.999 (100)	1001 1001.1001 1001 1001	20*
199.999 (200)	0001 1001 1001.1001 1001 1001	21*

*An additional counter card is used for this range.

Table 3-8 can be used to determine connections for BCD output digital counter cards.

To determine the applicable connections, you must know the stroke length and resolution. Subtract the resolution from the stroke length to obtain a maximum reading (column 1). Refer to column 7 to determine the decimal equivalent of each digit, knowing the desired decimal position. An example is worked out in Figure 3-12.

Table 3-8. BCD Output Connections

(1) Max reading	(2) No. of active bits	(3) Active Digits	(4) Pin connections Card A	(4) Pin connections Card B	(5) Binary Weight	(6) Digit	(7) Check Appropriate Column Resolution			
										other
			8		1					
			7		2	1				
			14		4	Least Significant	0001	001	01	
		1	13		8					
			12		1					
			11		2	2				
			18		4		001	01	1	
		2	17		8					
			16		1					
			15		2	3				
			20		4		01	1	1	
999	12	3	21		8					
1999	13	3-1/4	22		1					
3999	14	3-1/2	19		2	4				
7999	15	3-3/4	23		4		1	1	10	
9999	16	4	25		8					
19999	17	4-1/4	9*	8	1					
39999	18	4-1/2		7	2	5				
79999	19	4-3/4		14	4		1	10	100	
99999	20	5		13	8					
199999	21	5-1/4		12	1					
399999	22	5-1/2		11	2	6				
799999	23	5-3/4		18	4	Most Significant	10	100	10000	
999999	24	6		17	8					

* Used only with 4-1/4 digits. For 4-1/2 or more digits, 5th digit is on card B.

Example: **Order Specification:** Stroke = 200 inches
Resolution = .001 inches

Result: Maximum reading will be 199.999 inches (200 inches) this yields 5-1/4 digits, where the "1" is considered 1/4 of a digit. Go to column 1 and find 199999 = maxreading. The connections will be per (4), where the Least Significant digit is pins 8, 7, 14, and 13, card A. The Most Significant digit is pin 12 on card B. The next LSD is pins 8, 7, 14, and 13 on card B. Pin 9 is not used, due to footnote. Resolution for pin 12 is 100 place; for the 5th digit is 10 place; etc. Refer to middle column (7)

The following connection table is provided for BCD output digital counter card(s). To determine the applicable connections, the resolution and stroke length must be known, yielding a maximum reading, column 1. Refer to column 7 to determine the decimal equivalent of the particular digit in question, knowing the desired decimal point position.

(1) Max reading	(2) No. of active bits	(3) Active Digits	(4) Pin connections Card A	(4) Pin connections Card B	(5) Binary Weight	(6) Digit	(7) Check Appropriate Column Resolution			
										other
			8		1					
			7		2	1				
			14		4	Least Significant	0001	001	01	
		1	13		8					
			12		1					
			11		2					
			18		4	2	001	01	1	
		2	17		8					
			16		1					
			15		2					
			20		4	3	01	1	1	
999	12	3	21		8					
1999	13	3-1/4	22		1					
3999	14	3-1/2	19		2					
7999	15	3-3/4	23		4	4	1	1	10	
9999	16	4	25		8					
19999	17	4-1/4	[illegible]	8	1					
39999	18	4-1/2		7	2					
79999	19	4-3/4		14	4	5	1	10	100	
99999	20	5		13	8					
199999	21	5-1/4		12	1					
399999	22	5-1/2		[illegible]	2					
799999	23	5-3/4		[illegible]	4	6 Most Significant	10	100	10000	
999999	24	6		[illegible]	8					

* Used only with 4-1/4 digits. For 4-1/2 or more digits, 5th digit is on card B.

Figure 3-12. Sample BCD Output Connection Table

3.3.4 Wiring Procedure

The general wiring and checkout procedure is as follows:

1. Route the power and signal cables to the interface box. Do not run near high voltage lines or contacting equipment. Mark the power supply wires at the interface box J1 connector end of cable and connect the panel end of cable to the proper power supply terminals.

2. Connect the (+) and (-) gate signal wires to the counter card edge connector. Do not connect the edge connector to the card at this time.

3. Solder all cable wires to the appropriate J1 pins on the MS3116F12-10S box mating connector. Use heat shrink tubing over each solder connector to protect the connections from shorts. Make sure that cable shields do not make contact with the connector pins or the connector shell. Apply tape or a rubber boot over any exposed cable shield before tightening the cable clamps. Check for wiring shorts between pins after connector assembly.

CAUTION

Be sure all connections are correct before applying power. Voltages applied to the gate signal connector pins G or K (or optional D, E) will damage interface box.

4. Turn on power to the power supplies and take voltage readings on the J1 female connector between the appropriate pins. Check all other pins to ensure that no voltage is present.

5. Solder to the binary output on the digital counter card edge connector using ribbon cable or suitable wire harness.

6. Solder the 5 Vdc power supply to pins 1(-) and 2(+) on the counter card edge connector. Apply heat shrink tubing to the connector terminals to protect from shorts to other terminals.

7. Connect the power supply common for the ±15 V and +5 Vdc supplies together and ground them to earth ground. Refer to Figure 3-10.

8. Connect the counter card edge connector to the card. Connect the MS connector to the interface box J1 connector.

9. Plug in the transducer cable into the J2 interface box connector.

10. Apply power, and observe readings at the receiver device while moving the magnet along the transducer rod. If readings are satisfactory, go to Subsection 3.4 system calibration.

3.4 System Calibration

There are no adjustments on the interface box or the transducer. Instead, the system is calibrated at the counter card or by external means. The scaling (inches per count) is determined by a fixed frequency crystal oscillator, while the zero point is determined by resettable DIP switches on the counter card. Generally, the system components do not show shift, age, or drift over time, and recalibration is not necessary. However, calibration may be used to compensate for mechanical wear on external mechanical parts connected to the magnet or the transducer.

3.4.1 Re-zeroing the Series 80 Digital Counter Card

On Series 80 counter cards, the zero point is preset at the factory, using a pair of DIP switches, S1 and S2. Zero is set at 2 inches from the hex flange of the transducer, or at a distance specified by the customer. If reverse output is specified, the zero point is set at 5 inches or 7 inches from the tip of the transducer rod. The DIP switches are normally covered with RTV or otherwise protected, to prevent accidental resetting.

There are three ways of changing the zero setting:

a. **Mechanical Offset.**
The zero position can be adjusted by changing the mechanical offset of the magnet relative to the transducer rod. This requires a coupler device which permits a screw adjustment of the magnet.

The installer fabricates a coupler device to hold the magnet. The coupler should include adjustment screws that allow fine adjustments of the magnet along the transducer rod. Move the magnet to obtain a zero reading.

If the coupler does not allow magnet position adjustment, it can sometimes be used to lock the magnet in place, while shims or washers are used to move the transducer relative to the magnet (Do not attempt this if the unit is installed in a hydraulic cylinder).

b. **Software Programming.**
In some applications it is possible (and preferable) to maintain a zero offset in software at the receiver. This permits quick re-zeroing without adjusting the magnet or resetting the DIP switches.

For the detailed procedure, consult the manual for the receiver device. Move the magnet to the desired zero position and set the receiver reading to zero.

In most cases, the zero offset is determined by adding the binary complement to the reading observed with the magnet in the desired zero position.

c. **Resetting the Counter Card with DIP Switches**
For this procedure, the receiver device must be capable of reading each of the Counter Card output bits. For example, the System CRT or LED display may be connected to each bit connection on the input module. If this is not possible, a string of LEDs must be connected to the Counter Card connector to read each active bit (Refer to Figure 4-1 for a typical connection). Figures 3-13 and 3-14 show DIP switches S1 and S2, along with tables for determining the switch settings.

Binary Output

Take the following steps (Refer to Figure 3-13):

1. Before changing any DIP switch positions, record the factory-set positions for reference.

2. Move the magnet to the desired null position. Clamp it in place to prevent movement.

3. Reset all switch segments to the LO (closed) position, taking note of alignment marks on the board.

4. If a P.L.C. or readout device indicates the equivalent counts, write this value in row A of the diagram in Figure 3-11. Then convert this number to binary and write it in row B. To ensure that the count is correct, move the magnet through its stroke and observe the count change. For example, a 24-inch stroke unit with 0.001 resolution should yield a 24,000 count change.

   Alternatively, read each active bit on the counter card output and record into row B of the diagram.

5. Determine the complement of the binary number in row B, by changing 1s to 0s and 0s to 1s. Write this complement into row C.

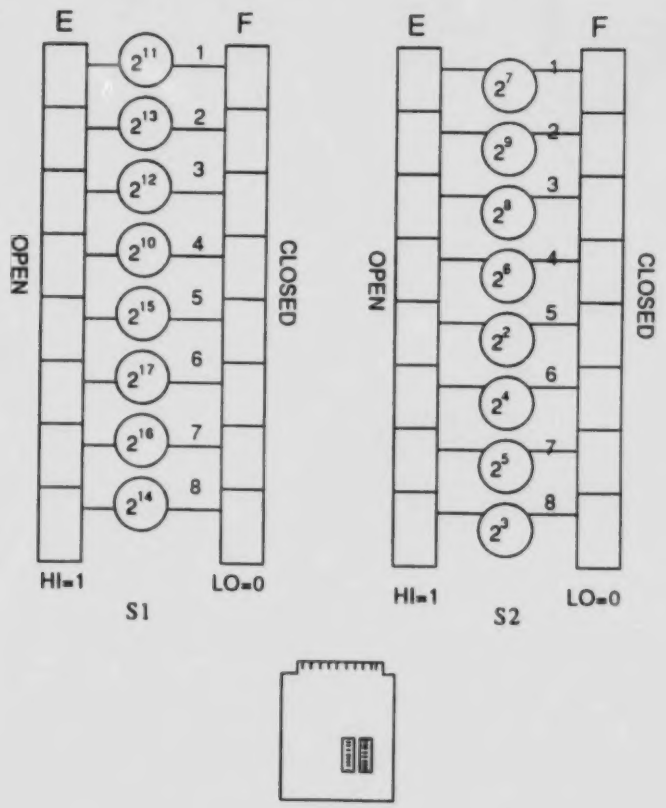
6. Use the number from row C to mark the columns E and F. If the corresponding bit from C is 1, mark and X in column E (open or HI). If the corresponding bit is 0, mark an X in column F (closed or LO).

7. Turn off power, then set each switch segment to the value (HI or LO) indicated by the Xs in columns E and F.

8. Apply power to the system and check that the output is now zero.

Pin Number*																			
Bit	2^{17}	2^{16}	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}	
A. Reading in Counts																			(if available)
B. Reading in binary																			(from LEDs or binary of A)
C. Complement																			(complement of B)
*Use Tables 3-4 to 3-8 to determine pin numbers																			

If value in row C is 1, mark X in column E.
If value in row C is 0, mark X in column F.



Dip switch settings should be viewed with the edge card connector facing upward.

Figure 3-13. Setting DIP Switches (Binary System)

BCD Output

Take the following steps (Refer to Figure 3-14):

1. Before changing any DIP switch positions, record the factory-set positions for reference.

2. Move the magnet to the desired null position. Clamp it in place to prevent movement.

3. Reset all switch segments to the LO (closed) position, taking note of alignment marks on the board.

4. If a CRT or other readout device indicates a decimal value (in inches, mm, or other units), convert this value from decimal to BCD binary, and record it in row B of the diagram in Figure 3-14. (Decimal-to-BCD conversion is explained on page 3-20.)

   Alternatively, read each active bit on the counter card output and record this BCD number in row A of the Diagram. Then convert row A to decimal, and record it in row B.

5. Subtract each digit in row B from 9, and record the result in row C.

6. Convert row C into BCD binary and record the result in row D.

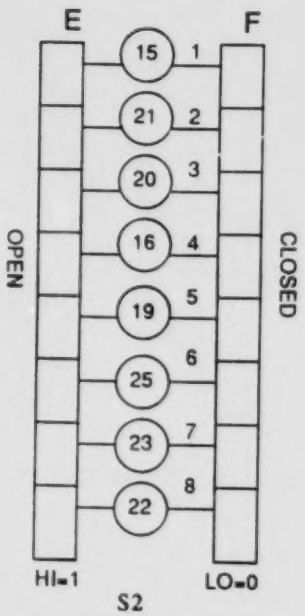
7. Use the number from row C to mark the columns E and F. If the corresponding bit from C is 1, mark an X in column E (open or HI). If the corresponding bit is 0, mark an X in column F (closed or LO).

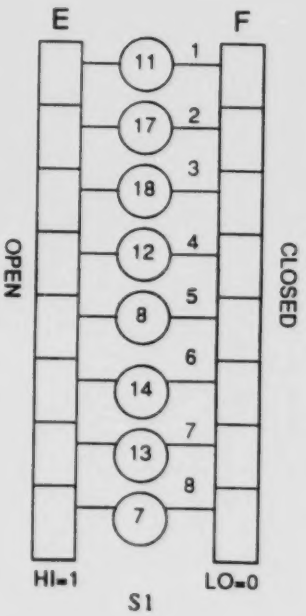
8. Turn off power, then set each switch segment to the value (HI or LO) indicated by the Xs in columns E and F.

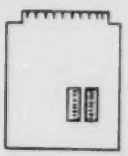
9. Apply power to the system and check that the output is now zero.

Digit	10^3				10^2				10^1				10^0				Not Used		
Bit	2^3	2^2	2^1	2^0	2^3	2^2	2^1	2^0	2^3	2^2	2^1	2^0	2^3	2^2	2^1	2^0			
Pin Number	25	23	19	22	21	20	15	16	17	18	11	12	13	14	7	8	9	10	
A. Reading in BCD																			(from LEDs, if used)
B. Reading in Decimal																			(from BCD indicator, if used)
C. 9 - Decimal																			Subtract B from 9
D. Converted to BCD																			Convert C to BCD

If value in row D is 1, mark X in column E.
If value in row D is 0, mark X in column F.







Dip switch settings should be viewed with the edge card connector facing upward.

If a second counter card is provided (for 5 or 6 digit BCD), use this table in addition to the table above

Digit	10^4			
Bit	2^3	2^2	2^1	2^0
Pin Number	13	14	7	8
A. Reading in BCD				
B. Reading in Decimal				
C. 9 - Decimal				
D. Converted to BCD				

Figure 3-14. Setting DIP Switches (BCD System)

3.4.2 Re-zeroing the Series 60 Digital Counter Card (former design)

The Series 60 Counter Card does not contain any internal adjustment for zero setting in the field. Re-zeroing this card can only be done by mechanical offset or software programming. These procedures are described earlier in Subsection 3.4.1.

3.4.3 Scaling Series 60 and Series 80 Digital Counter Cards

1. Scaling is not normally required for Digital Counter Cards, because most digital systems are supplied as scaled systems. (Refer to the earlier Subsection 1.3.1 for a discussion of scaling.)

2. Scaling is required for systems supplied as "unscaled" systems, or if the counter card is not matched to the transducer serial number. Scaled systems will have a discrete scale factor, such as 0.001 inches per count, and do not require scale factor determination.

   To determine the scale factor (or to check system performance), move the magnet to a known measured position on the transducer near full stroke. Observe the output and record it.

   The scale factor is determined by dividing the measurement by the observed number of counts or the observed output in BCD. As an example,

   Measurement = 36.000 inches
   Reading = 35,420 counts (or 35.420 in BCD)

   $$\text{Scale Factor} = \frac{36}{35{,}420} = 0.0010163 \text{ inches per count (inches per inch in BCD)}$$

3. For systems that will be used for only one or more discrete positions, move the magnet to the known measured positions that will be repeated during system operation. Observe and record each reading.

   Compare each observed reading to the measured reading and record results. Use the observed readings in software programming as the set point or control points.

   For greater system accuracy, repeat this step and average the readings.

NOTE

To obtain maximum system accuracy, perform the above procedures at or near the actual system operating conditions.

4. For systems that are used for continuous readings or variable set points, apply the scale factor in Step 2 to software programming so that each reading is multiplied by the scale factor (consult receiver device manual). Continue to Step 5.

5. Move the magnet to a known, measured position at or near half of stroke. Observe the reading and compare to the measurement. If the reading varies by more than ±0.05% full stroke, repeat Step 2 using a different measurement near full stroke. Check the new scale factor by performing Step 5 again.

NOTE

To obtain maximum system accuracy, several scale factors should be calculated using different measurements and the factors should be averaged. Readings should be taken at or near actual system operation conditions.

6. If the readings do not relate to the stroke position, or appear erratic, refer to Section 4 for troubleshooting information.

Section IV
Troubleshooting

This section consists of troubleshooting procedures to be used when operational problems are encountered.

NOTE

The following procedures are for general troubleshooting purposes. Purchase of replacement components should not be determined solely upon results of these tests. Consult MTS Temposonics for recommendations before purchasing replacement system components.

4.1 General

If the output signal is erratic or unchanging (random), the first procedure is to turn off power and recheck Subsections 3.3.1, 3.3.2, and 3.3.3 for possible errors in mechanical or electrical installation. Once all procedures have been checked, continue for diagnostic test procedures to determine the cause of fault.

The possible causes of faulty output are listed below in order of frequency (probability) of occurrence, and should be checked in order.

		References
1.	Improper power supply/power connection	Figure 3-10 and Subsection 4.2
2.	Mismatched system components*	Subsection 1.3
3.	Ground loops/improper grounding*	Figure 3-11
4.	Improper wiring procedure for J-1 on DIB power and signal connections	Figure 3-10
5.	Improper wiring procedure for J2 on DIB to transducer	Subsection 3.3.1
6.	Improper wiring procedure for counter card connections*	Subsection 3.3.3
7.	Incorrect receiver device or software*	Subsection 4.4
8.	Improper magnet mounting*	Subsection 3.2
9.	EMI noise, affecting transducer, transducer cable, or DIB/counter card cable*	Figures 3-10 and 3-11
10.	Circuit fault within interface box	
11.	Circuit fault within counter card	
12.	Circuit fault within transducer	

* Will cause erratic or unstable output

The equipment required for diagnostic testing is:

1. Analog or digital voltmeter
2. Circuit tester or ohmmeter
3. Oscilloscope, 50 mHz (15 mHz minimum) (dual channel preferred)

4.2 Power Supply Check

This procedure will determine if the power supply rating is sufficient, or if there is a voltage drop occurring in the field wiring.

Perform the following procedure to check power supply voltage and connections at the interface box.

1. Remove power and disconnect J-1 10 pin connector from interface box. Also remove edge connector from counter card. Turn power on and check open circuit voltages at the connector pins of the box mating connector.

2. Pin H should read +15 with respect to A.
   Pin B should read -15 with respect to A.
   Pin C should read +5 with respect to A.

3. Check power supply voltages under load as follows: Connect a 150 ohm resistor (or similar 1.5 watt, 12-15 Vdc load*) between pins H and A and read the voltage across the resistor. The value should be 14.25 Vdc minimum.

4. Connect a 220 ohm resistor (or similar 1 watt, 12-15 Vdc load*) between pins B and A and read the voltage across the resistor. The value should be -14.25 Vdc minimum.

5. Connect a 10 to 12 ohm resistor (or similar 2 watt, 5-6 Vdc load*) between pins B and A and read the voltage across the resistor. The voltage should read +4.75 Vdc minimum.

Perform the following procedure to check the power supply voltage and connections at the 5 volt power supply.

1. Connect a 4 ohm, 5 watt resistor (or similar 1.2 amp load*) across the +5 Vdc terminals of the power supply. The voltage should be +4.75 Vdc minimum.

2. Reconnect the counter card and digital interface box. Read the voltage at the counter card edge connector, pin 2 with respect to pin 1. The voltage should read +4.75 Vdc minimum.

---

* *Automotive 12 or 6 Vdc bulbs of the proper wattage are acceptable alternatives.*

4.3 Wiring

Improper wiring between the transducer and J-2 box connector or the counter card and J-1 box connector can cause either an erratic output or complete loss of output signal.

The following instructions should be followed to check all connections.

1. Disconnect or remove dc power to the system.

2. Trace all wiring from the counter card to the interface box. Refer to Figure 3-8, and instructions Subsection 3.3.2 for proper connection diagrams and cable types.

3. Trace all wiring from the transducer to the interface box J-2 connector. Ensure that maximum cable length and type is observed. Refer to Table 3-1A and installation Subsection 3.3.1 for color codes, cable numbers etc.

4. Check system grounds. Figure 3-11 shows a typical circuit diagram with the required and optional grounds. Ensure that circuit ground is made at one location only to avoid ground loops. If erratic or unstable output is encountered, recheck all earth grounds and cable grounds.

5. Connect an oscilloscope to the + and - gate signals at the counter card edge connector, pins 5 and 4 with respect to circuit ground pin 1. Check for presence of each gate separately, since loss of either gate will cause loss of output. If the pulse width modulates with change in magnet position, continue to Subsection 4.4 for counter card testing.

4.4 Counter Card Digital Output Test Procedure

The counter card output, (14-18 bits typical), is a true high TTL level signal nominal 0 to 5 volts dc.

The receiver device must be selected to interface with the TTL level signal of the counter card. Most devices offer a TTL input option or a specific model selection designed for TTL only.

If the user suspects an improperly selected or malfunctioning receiver device, the counter card output may be tested using LED's.

Perform the following procedure:

1. Disconnect the receiver device from the binary output of the counter card. This is usually performed at the receiver device input terminals.

2. Connect 4 or more LED's between the binary output and power supply ground as shown in Figure 4-1. Select the bits (or digit) which will give a reading which is easily interpreted. (Four of the "middle" bits for natural binary; tenths or units place for BCD). The LED's should be rated for 3-5 Vdc, 50 mA maximum. The LEDs light when the bit is high. (Note that output voltage will drop under load - see TTL data books.)

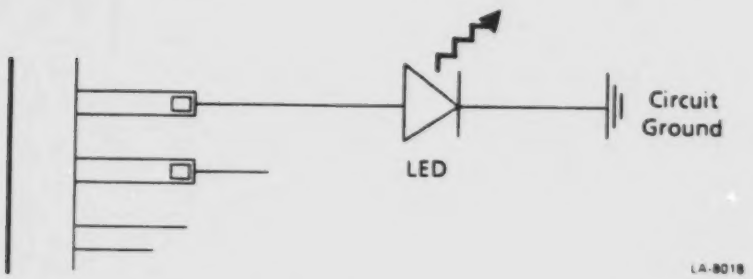


Figure 4-1. Testing Counter Card Output

3. With the above test set-up procedure, some of the LED's should light immediately. If no LED's light, move the magnet through the stroke of the transducer and ensure that one or more LED's light. If none respond, recheck the wiring of the LED's and the power supply connections to the counter card (pins 1 and 2).

4. To check the counter card reading move the magnet between two measured positions on the stroke, and record the LED readings, as "hi" or "lo". Take the complement of the readings, and calculate the decimal equivalent of the readings. For example, in natural binary, a decimal equivalent is:

Table 4-1. LED Test

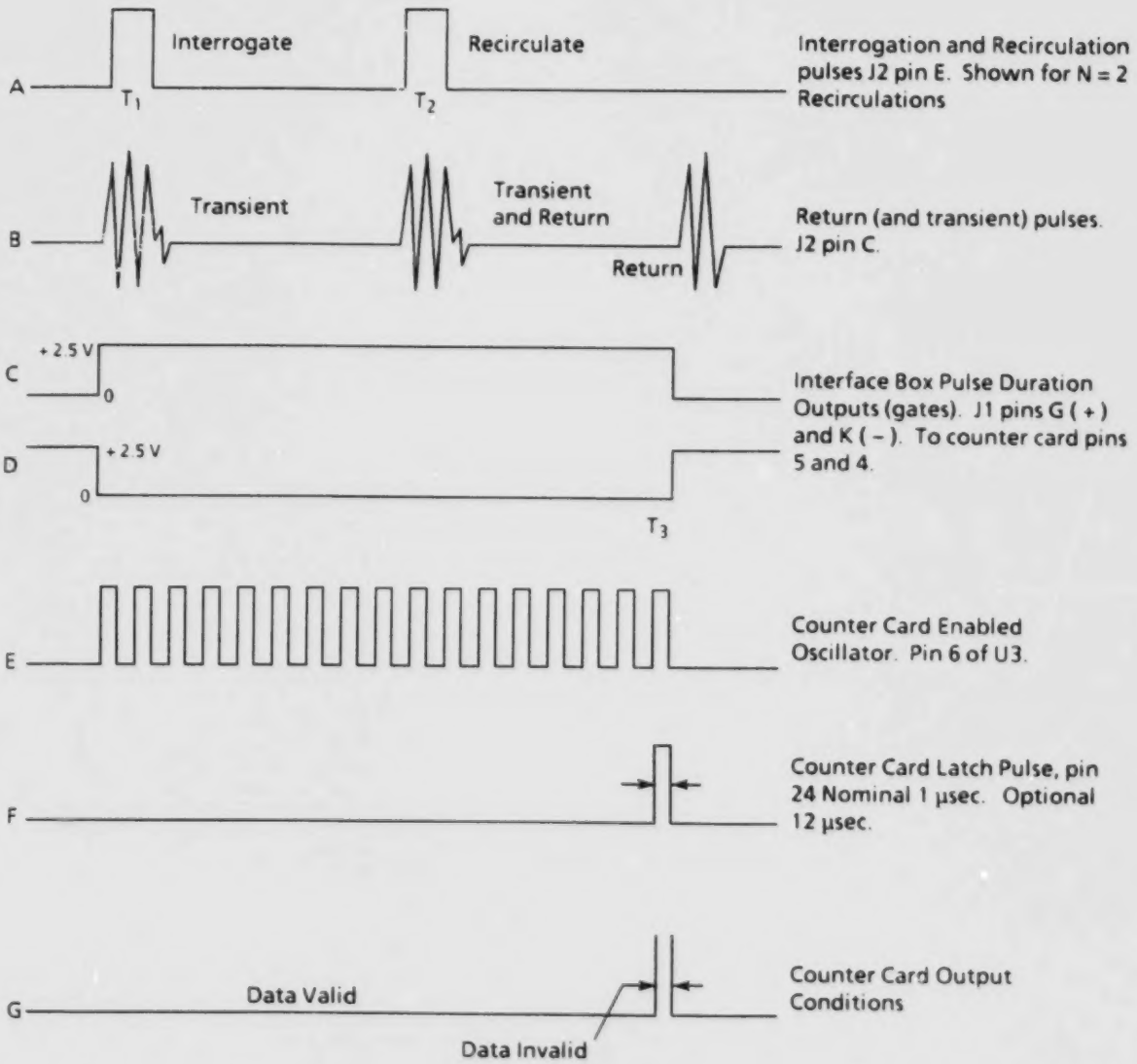
Bit Number	LED	Complement (A)	Decimal Weight (B)	A x B
2^{0*}			0.001	
2^{9}	Hi = 1	Lo = 0	0.512	0
2^{10}	Lo = 0	Hi = 1	1.024	1.024
2^{11}	Hi = 1	Lo = 0	2.048	0
2^{12}	Lo = 0	Hi = 1	4.096	4.906
			Sum =	5.930 Inches of stroke

* Shown for reference purposes

Repeat this table for position 2, and compare the inches of stroke measured to the inches of stroke observed.

NOTE

A change in reading between 2 points on the stroke is a general indication of proper system operation.



T_3 = 9.05 µsec/inch × N × (position + 4.5 inches) (approximate)

LA-A137

Figure 4-2. System Level Signal Timing

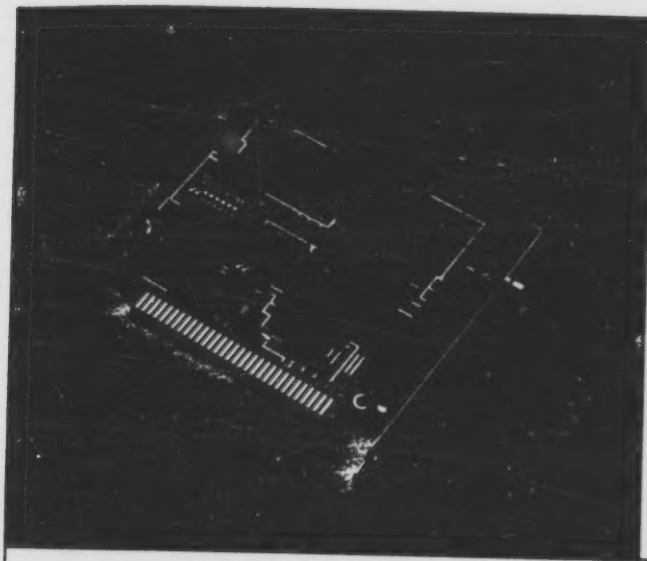
APPENDIX C

METRABYTE PI012 24 BIT DIGITAL I/O INTERFACE

MBC MetraByte Corporation

DATA ACQUISITION AND CONTROL FOR IBM PC/XT/AT AND COMPATIBLE COMPUTERS

24 BIT PARALLEL DIGITAL I/O INTERFACE MODEL PI012



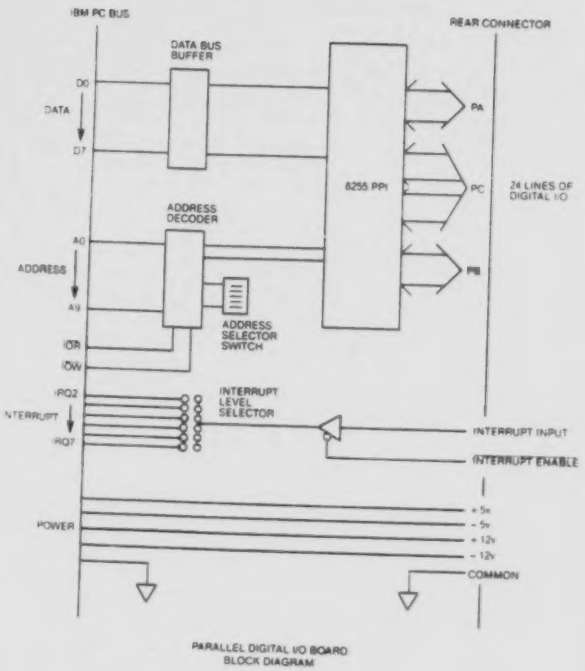
FEATURES

- 24 TTL/DTL Digital I/O Lines
- ±12V, ±5V Power from IBM PC/XT
- Unidirectional, Bidirectional strobed I/O
- Interrupt Handling
- Direct Interface to wide range of peripherals
- Plugs into IBM PC/XT/AT Bus
- Handshaking

APPLICATIONS

- Contact Closure Monitoring
- Plotter Interface
- Printer Interface
- Digital I/O Control
- Magnetic Tape Units
- Useful with A/D's and D/A's
- Card Reader Interface

BLOCK DIAGRAM



PARALLEL DIGITAL I/O BOARD BLOCK DIAGRAM

IBM IS A REGISTERED TRADEMARK OF INTERNATIONAL BUSINESS MACHINES INC.

FUNCTIONAL DESCRIPTION

MetraByte's parallel digital I/O card provides 24 TTL/DTL compatible digital I/O lines, interrupt input and enable lines and external connections to the IBM P.C.'s bus power supplies (+5v, +12v, −12 & −5v). It is a flexible interface for parallel input/output devices such as instruments and displays and user constructed systems and equipment.

24 digital I/O lines are provided through an 8255-5 programmable peripheral interface (P.P.I.) I.C. and consist of three ports, an 8 bit PA port, an 8 bit PB port, and an 8 bit PC port. The PC port may also be used as two half ports of 4 bits, PC upper (PC4-7) and PC lower (PC0-3). Each of the ports and half ports may be configured as an input or an output by software control according to the contents of a write only control register in the P.P.I. The PA, PB & PC ports may be read as well as written to. In addition, certain other configurations are possible for unidirectional and bidirectional strobed I/O where the PC ports are used for control of data transfer and interrupt generation etc. Users are referred to the Intel 8255-5 data sheet for a complete technical description and summary of the various operating modes of the P.P.I.

Interrupt handling is via a tristate driver with separate enable (interrupt enable — active low). This may be connected to any of the interrupt levels 2-7 available on the IBM P.C. bus by means of a plug type jumper on the board. Handling of an interrupt is controlled by the 8259 interrupt controller in the IBM P.C. and this is set by BIOS on system initialization to respond to positive (low-high) edge triggered inputs. Users must program the 8259 to respond to their requirements and set up corresponding interrupt handlers.

Power from the IBM P.C. is available on the connector from the computer bus. Users should observe the current capacity limits detailed on page 2-37 of the IBM P.C. "Technical Reference Manual" and make allowance for the power consumption of any other expansion boards that may be in use.

MBC and MetraByte are trademarks of MetraByte Corp.

BASE ADDRESS SWITCH

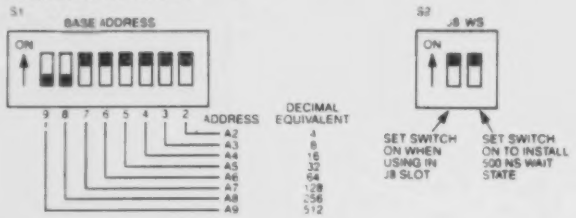
The 8255-5 P.P.I. uses 4 I/O address locations which are fully decoded within the I/O address space of the IBM P.C. The base address is set by an 8 position DIP switch (see Fig. 1) and can in theory be placed anywhere in I/O address space, but base addresses below FF hex (255 decimal) should be avoided as this address range is used by the internal I/O of the computer. the 200-3FF hex (512-1023) address range *provides extensive unused areas of I/O space, though you should* check with page 2-23 of the "Technical Reference Manual" for possible conflicts with commonly installed peripherals. The address map for the P.P.I. registers is:—

Base Address			
	+0	PA port	read/write
	+1	PB port	read/write
	+2	PC port	read/write
	+3	Control	write only

Switch 2 performs two functions. First, it allows the PIO-12 to be operated in the J8 slot of an IBM XT (the slot furthest to the right). Switch 2's second function to install a 500 nS wait state. The use of this wait state may be required when using the PIO-12 in computers which have greater than 8 Mhz system clocks.

Switch Settings

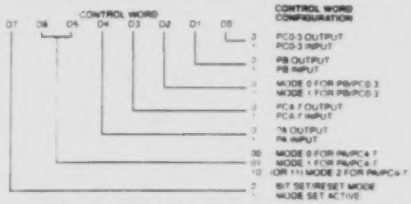
FIG. 1 BASE ADDRESS SWITCH SETTING FOR &H300 (300 HEX/768 DECIMAL)



SWITCHES HAVE DECIMAL VALUES AS ABOVE IN THE "OFF" POSITION. IN THE "ON" POSITION DECIMAL VALUE IS ZERO

PROGRAMMING

Programming is simple whether from assembly language or BASIC. The P.P.I. should first be configured in the initialization section of your program by writing to the control register. On power up or reset, all ports are configured as inputs. A wide variety of configurations are possible by writing the appropriate control code. Some examples are detailed:—



Note that D7 must be high (=1) to set the configuration of the ports. There are three possible operating modes, and the PA/PC4-7 and PB/PC0-3 groups may be in different modes at the same time:—

Mode 0 - Basic I/O, all ports are I/O ports
Mode 1 - Strobed I/O, part of the PC port controls data transfer
Mode 2 - Bidirectional I/O on PA only, part of PC controls data transfer

Some examples:—

PA input, PB output, PC0-3 input, PC4-7 output
Control word = 1001 0001 binary or 91 hex

Strobed output on PB, PA output, PC0-3 control, PC4-7 input
Control word = 1000 1100 binary or 8C hex

To program:

1) First write to the control register to set configuration e.g. in BASIC:—
   xxxx OUT (Base address +3), &H91
2) Then you can access the ports as required. For example to read PA:—
   xxxx X% = INP (Base address + 0)
   To write to PB:—
   yyyy OUT (Base address + 1), DATA
   To read PC:—
   zzzz Z% = INP (Base address + 2)
3) Once the configuration has been set in the initialization, the P.P.I. will remain in that configuration until a further write to the control register. Users should be warned that it is a property of the 8255 P.P.I. that all port registers are cleared by a write to the control register. If you intend to make repeated changes of configuration in your program, you may also need to make provision for restoring data to cleared ports.

The following programming example demonstrates how input bits of the PC Port can be used to monitor the status of two points and when their condition is met, will output a binary value to the PB Port.

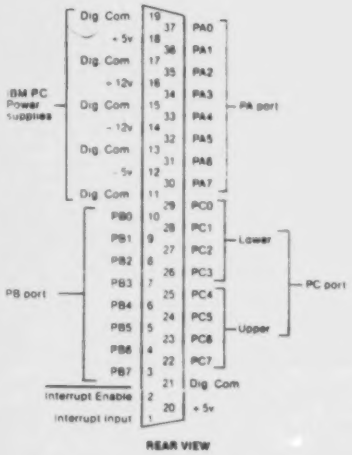
```
10    OUT &H303, &H89
20    K%=INP(&H302)
30    IF (K% AND 5)=5 THEN OUT &H301,9
40    IF (K% AND 5)=0 THEN OUT &H301,0
50    GOTO 20
```

If Input Port PC Bits 0 and 2 are true then Output A Binary 9 (Bits 0 and 3) from the PB Port, otherwise Output A zero.

CONNECTOR PIN ASSIGNMENTS

All digital I/O is through a standard 37 pin D type male connector that projects through the rear panel of the computer. For soldered connections a standard 37 pin D female (ITT/Cannon DC-37S or equivalent) is the correct mating part, and can be ordered from MetraByte as part #SFC37. Insulation displacement (flat cable) connectors are available from Amp (#745242-1), 3M, Winchester, Robinson-Nugent etc.

The connector pin assignments are as follows:



SPECIFICATIONS

LOGIC INPUTS AND OUTPUTS	Min.	Max.
Input logic low voltage	−0.5	0.8 volts
Input logic high voltage	2.0	5.0 volts
Input load current PA, PB, PC port (0 < Vin < 5v)	-10	+10 uA
Input low current, interrupt inputs	—	−0.4 mA
Input high current, interrupt inputs	—	20 uA
Output low voltage PA, PB, PC ports (Isink = 1.7 mA)	—	0.45 volts
Output high voltage PA, PB, PC ports (Isource = 200 uA)	2.4	— volts

All outputs and inputs are TTL/DTL compatible and outputs will drive 1 standard TTL load (74 series) or 4 LSTTL (74LS) loads. CMOS compatibility can be obtained by connecting a 10Kohm pullup resistor from the input or output to +5v.

BUS LOADING

Power consumption: 170 mA typ. @ +5v

ENVIRONMENTAL

Operating temperature range: 0 to 50 deg. C.
Storage temperature range: −40 to +100 deg. C.
Humidity: 0 to 90% Non-Condensing
Size: Half slot

PIO-12
STA-U **Optional Screw Terminal Board**
C-1800 **STA-U to PIO-12 Cable**

APPENDIX D

ANALOG DEVICES 3B18-01 HIGH BANDWIDTH SIGNAL CONDITIONER

2.1.7 MODEL 3B18

FEATURES
Accepts Strain Gage Input
20kHz Bandwidth
Provides Bridge Excitation
Dual High Level Outputs
Voltage: ±10V
Current: 4-20mA/0-20mA
High Accuracy: ±0.1%
Low Drift: ±3μV/°C
Input Protection: 130V rms Continuous
Reliable Pin and Socket Connections

FUNCTIONAL DESCRIPTION

The 3B18 is a wideband input module that is designed to accept signals from full four arm bridge strain gage-type transducers on the input screw terminals. The 3B18 provides a switch selectable excitation of +3.3V or +10.0V and can be used with 100Ω to 10kΩ strain gage bridges. The module has a 20kHz bandwidth to interface to dynamic signals.

Figure 2.1.7.1 shows a block diagram for the model 3B18. A regulated bridge excitation of either −3.3V or +10.0V is provided on screw terminals 1 and 4. Input protection of up to 130V is provided for the input and excitation circuitry. The signal is amplified to give the high level voltage output. Both the voltage and current outputs can be independently adjusted over a ±5% span range for zero and span with the front panel accessible potentiometers. The current output, which has 130V output protection, interfaces with user equipment through screw terminal connections.

Model 3B18 requires a ground return for the input connection to return the bias current to ground.

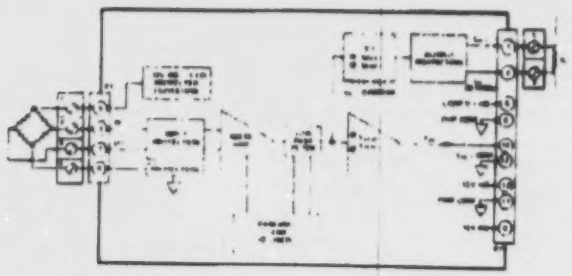


Figure 2.1.7.1 3B18 Functional Block Diagram

FINE CALIBRATION

Each model is factory calibrated for a specified range to provide zero and span accuracy of ±0.1% of span. The excitation voltage should be used in the calibration setup since it has a ±2% tolerance. User accessible zero and span trim potentiometers providing a ±5% adjustment range permit precise field calibration of both the voltage output and the current output. The two outputs are adjusted independently and are noninteractive. The following nonrecursive procedure is recommended:

1. Connect model 3B18 as shown in Figure 2.1.7.1 with R_L = 250Ω.
2. Apply V_{IN} = 0 volts, adjust V_Z for V_{OUT} = 0V ±10mV and I_Z for I_{OUT} = 4mA ±0.016mA or the voltage measured across R_L = +1V ±4mV.
3. Apply V_{IN} = +Full Scale, adjust V_S for V_{OUT} = +10V ±10mV and I_S for I_{OUT} = 20mA ±0.016mA or the voltage measured across R_L = +5V ±4mV.

If a 0-20mA output is desired for a 0 to +10V output, adjust I_Z for I_{OUT} = 0mA ±0.020mA in step 2 and I_S for I_{OUT} = 20mA ±0.020mA in step 3. (A typical minimum output current is 10μA with 0-20mA operation).

If the current output is to be proportional to a −10V to +10V output instead of a 0 to +10V output, I_Z should be adjusted for a −Full Scale input in step 2.

CUSTOM CALIBRATION

A powerful custom ranging capability is provided with a plug-on ranging card, AC1310. If a special gain is desired, it can be provided by ordering the externally programmable version of the desired module and the AC1310 which houses a user supplied resistor that determines the span of the new range. If desired, the 20kHz bandwidth can be reduced with user supplied capacitors installed in the AC1310. A special range can also be factory configured. Consult the factory for details.

The basic transfer function of the 3B18 is:

$$V_O = G \times V_{IN}$$

Where V_O = Output Voltage
G = Gain
V_{IN} = Input Voltage

There is no provision for zero suppression beyond the ±5% available with the zero potentiometers.

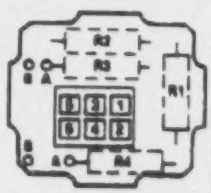
GAIN SETTING RELATION

With the AC1310, the gain G is set by R_3A which is determined from the following:

3B18

$$R_3A = \frac{200k\Omega}{G}$$

Gain G is a ratio of the change of output to the input change that produced it. If there is to be no bandwidth reduction, R_4A and R_1 should be left open. The gain-setting resistor should be installed as indicated in Figure 2.1.7.2.



	GAIN SELECTION ONLY	GAIN SELECTION AND BANDWIDTH REDUCTION
R_1	Open	Filter Capacitor, C_2
R_2	Open	Open
R_3A	Gain Resistor	Gain Resistor
R_4A	Open	Filter Capacitor, C_1

Figure 2.1.7.2 3B18 Custom Ranging

SPECIFICATIONS

(typical @ + 25°C and ± 15V, + 24V dc power)

Model	3B18
Inputs	
3B18-01	± 30mV at 3mV/V Sensitivity
3B18-02	± 10mV at 3mV/V Sensitivity
Outputs	± 10V to ± 2mA 4-20mA or 0-20mA in R_L = 0 to 850Ω[1]
Maximum Current for Input Overload	31mA
Accuracy[2]	± 0.1% span
Nonlinearity	± 0.01% span
Stability vs. Ambient Temperature	
Voltage Output	
Zero	± 3μV/°C (RTI)
Span	± 0.0025% reading/°C
Current Output (w.r.t. Voltage Output)	
Zero	± 0.0025% span/°C
Span	± 0.0025% reading/°C
Excitation Voltage	± 0.0015%/°C
Bridge Excitation (User Selectable)	+ 10V, + 3.33V
Excitation Tolerance	± 2%
Bridge Resistance Range	
@ V_{EXC} = + 10.0V	300Ω to 1kΩ
Bridge Resistance Range	
@ V_{EXC} = + 3.33V	100Ω to 10kΩ
Common Mode Voltage, Input to Output	± 10V
Common Mode Rejection @ 50Hz or 60Hz 1kΩ Source Unbalance	100dB
Differential Input Protection[3]	130V rms, Continuous
Voltage Output Protection	Continuous Short to Ground
Current Output Protection	130V rms, Continuous
Zero and Span Adjustment Range[4]	± 5% of span
Bandwidth	20kHz
Response Time to 99% Span	24μs
Input Resistance	100MΩ
Input Bias Current	25nA
Power Supplies[5]	
± 15V Input Supplies Range	
(Rated Operation)	± (13.5V to 16.5V)
Supply Rejection	± 0.01% span/V
Supply Current	+ 50mA, − 15mA
+ 24V Loop Supply Range	+ 13.5V to + 30V
Supply Rejection	0.0002% span/V
Supply Current	27mA (at + FS)
Size	3.150" × 0.775" × 3.395"
Environmental	
Temperature Range, Rated Performance	− 25°C to + 85°C
Storage Temperature Range	− 55°C to + 85°C
Relative Humidity Conforms to MIL Spec 202	0 to 95% @ 60°C noncondensing
RFI Susceptibility	± 0.5% span error, 5W @ 400MHz @ 3ft

NOTES
[1]For a 0-20mA range, a typical minimum output current is 10μA.
[2]Accuracy spec includes the combined effects of repeatability, hysteresis and linearity. Does not include sensor or signal source error.
[3]Includes excitation circuitry.
[4]Custom calibration may be accomplished with a custom ranging card, AC1310.
[5] + 24V dc power is only needed for driving the current output at up to 850Ω. If only voltage output is used, or a current output load of 400Ω or less is desired, ± 15V is all that is required.
Specifications subject to change without notice.

ORDERING INFORMATION

Input Ranges	Model Number
Externally Programmable	3B18-00
± 30mV, 3mV/V Sensitivity with 10V Excitation	3B18-01
± 10mV, 3mV/V Sensitivity with 3.33V Excitation	3B18-02

FREQUENCY RESPONSE

Model 3B18's standard bandwidth is 20kHz. The bandwidth can be set for any value less than 20kHz using the AC1310. The required capacitors, C_1 and C_2, are determined from the following relations:

$C_1 = 8.4\mu F / F_C$
$C_2 = 4.2\mu F / F_C$

Note: For values of C_1 below 3nF, reduce C_1 by 320pF and C_2 by 160pF.

where F_C is the desired cutoff frequency. Bipolar capacitors capable of withstanding ± 10V should be used. The space limitations of the AC1310 must be considered when choosing the required capacitors. These capacitors are to be installed in the positions designated as R_4A and R_1 respectively as indicated in Figure 2.1.7.2. The AC1310 can be used to reduce the bandwidth in factory ranged units.

EXCITATION VOLTAGE SELECTION

The excitation voltage is selected by dip switches accessible behind the sliding door on the front of the module, just below the zero and span trim potentiometers. The switch settings for the excitation voltage are indicated in Table 2.1.7.1. No other combinations of switch settings are useful.

When the excitation terminals are open-circuited and the 3.33V excitation voltage is selected, the actual terminal voltage will rise to over 8V. This is not a harmful effect, but must be considered when the product is being tested. A load as small as 0.25mA will bring the voltage down to its specified value.

Excitation Voltage	Switch 1	Switch 2
10.0V	OFF	ON
3.33V	ON	OFF

Table 2.1.7.1 3B18 Excitation Voltage Switch Selections

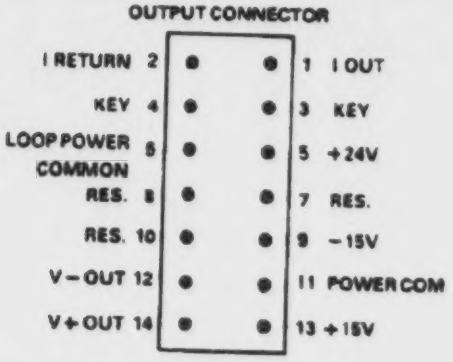
LIMITS

The ranging card can be used to create a wide range of special transfer functions, but there are practical limits that must be observed. The allowable input voltage for the 3B18 is ± 10V. The range of the module's voltage output adjustment is at least + 0.5V at the module output and can, therefore, correct any input offset error of less than 0.5V/Gain. If possible, the resistor should be 1% tolerance, 10ppm. See Appendix A for a detailed discussion of limits, error contributions, and temperature effects of the ranging card.

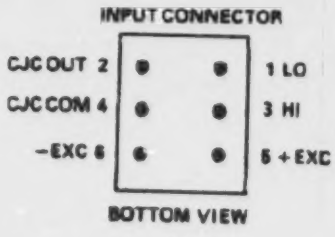
If a special input range is desired, it can be provided with the externally programmable version of the desired module, the plug-on ranging card, and user supplied resistors. See the discussion of the module of interest within the User's Manual for further details.

Each input module has two user programmable jumper options. One option allows the user to program the current output to be proportional to either the 0 to + 10V output or a - 10V to + 10V output. The second option allows the user to determine if the current output is 4-20mA or 0-20mA. All modules are shipped from the factory configured so that the current output is proportional to the 0 to + 10V output and each current output is 4-20mA. If the push-on jumpers are changed, the zero and full scale points will shift by approximately 0.25% of span and will need to be recalibrated to remove this error.

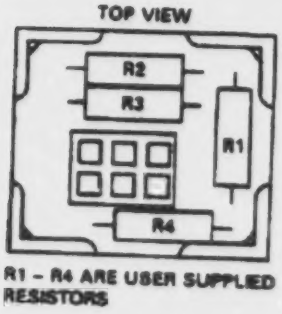
The current output of all input modules requires a grounded return. The grounded return of the current output can only be used for the return of ONE MODULE. Two or more modules SHOULD NOT BE connected to the same RETURN terminal. If several current loops are to be returned with one ground, that connection should be made to the Loop Common on the DC POWER connector.



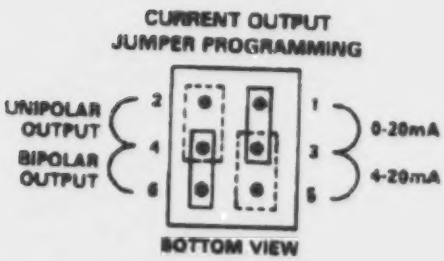
Output Connector



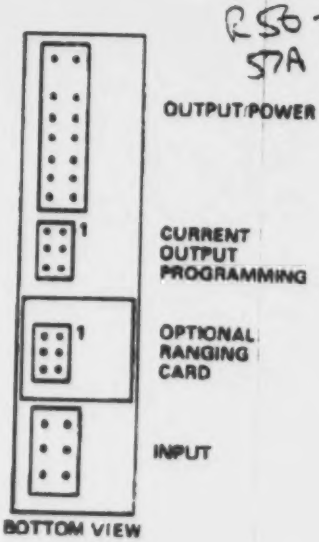
Input Connector



Ranging Card



Jumper Options



Bottom View of Connectors

Figure 2.1.2 Input Module Connectors

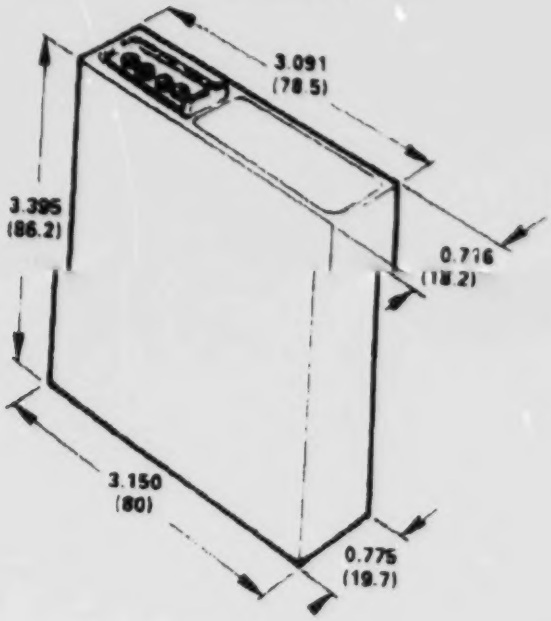
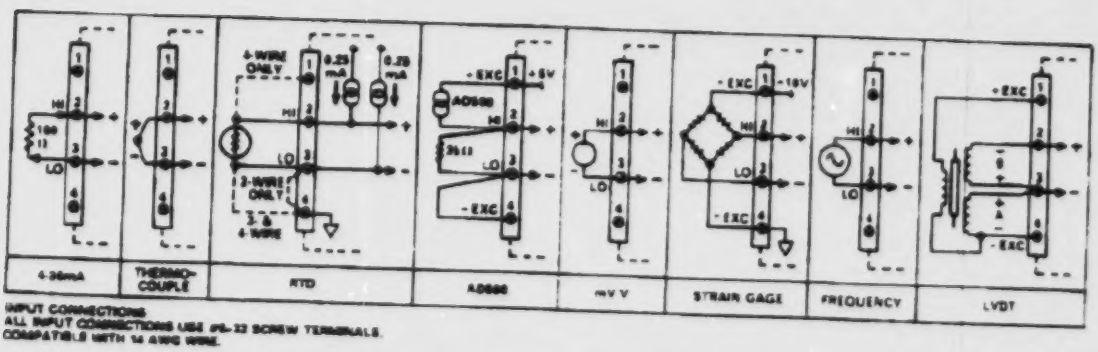


Figure 2.1.3 Module Outline Dimensions (Dimensions shown in inches and (mm)).



INPUT CONNECTIONS
ALL INPUT CONNECTIONS USE #6-32 SCREW TERMINALS.
COMPATIBLE WITH 14 AWG WIRE.

Figure 2.1.4 Module Input Connections

APPENDIX E

ENDEVCO MODEL 7231C-750
PIEZORESISTIVE ACCELEROMETER

ENDEVCO® MODEL 7231C-750
PIEZORESISTIVE ACCELEROMETER
±750 g Rugged

The Endevco® Model 7231C-750 is a rugged, undamped, medium g-level piezoresistive accelerometer designed specifically for automotive crash test studies. This transducer has become the FMVSS 208 standard for anthropormorphic dummy response studies, providing measurement of head, chest, pelvis and other body accelerations in the search for safer vehicle and restraint design.

The Model 7231C utilizes two active silicon strain gages and two fixed resistors (500Ω each) arranged in a wheatstone bridge configuration. This configuration provides for a low impedance output of 150 mV full scale with 10 Vdc excitation and shunt calibration capability. The Model 7231C utilizes an aluminum housing and an open connector cover to allow for solder terminal pins to be accessed. A closed cover configuration with cable strain relief shielding the solder pin terminals is available on special order. This unit is also available with increased performance, providing for 1% transverse sensitivity ("T" option), and ± 3% tolerance on sensitivity ("S" option) on special order.

(All values are typical at +75°F (+24°C) unless otherwise specified.)

PERFORMANCE

RANGE	g	± 750
SENSITIVITY[1] (at 10 Vc excitation, ref 100 Hz) Typical/Minimum	mV/g	0.20/0.15
NON-LINEARITY & HYSTERESIS (% of reading, max, to full range)	%	±1
FREQUENCY RESPONSE (±5% max, ref 100 Hz)	Hz	0 to 2000
MOUNTED RESONANT FREQ[1]	Hz	25 000
DAMPING RATIO		0.005
TRANSVERSE SENSITIVITY (max)[2]	%	3
THERMAL SENSITIVITY SHIFT (ref + 75°F [+24°C])	%	+3/0/-3
	°F	-10/+75/+150
	°C	-23/+24/+66
ZERO MEASURAND OUTPUT (max)	mV	±25
THERMAL ZERO SHIFT (max)[3]	mV	±15

ELECTRICAL

EXCITATION[4,5]	Vdc	10.0
INPUT RESISTANCE [4]	Ω	525
OUTPUT RESISTANCE	Ω	525
INSULATION RESISTANCE (minimum at 100 Vdc)	MΩ	100, leads to case
GROUNDING		Case isolated from sensors

PHYSICAL

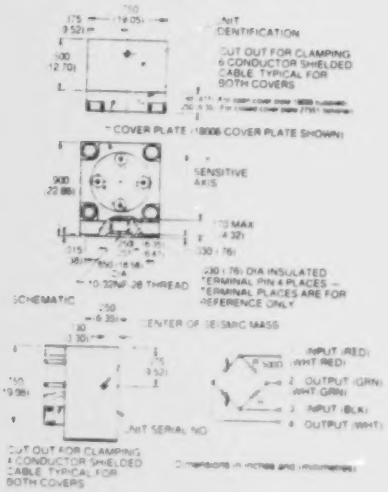
WEIGHT (excluding cable)	oz (gm)	0.85 (24)
CASE MATERIAL		Aluminum alloy
ELECTRICAL CONNECTIONS		Four solder pins. Cable shield may be clamped to case with cover plate
MOUNTING/TORQUE		Hole for 10-32 mounting stud 18 lbf-in (2 Nm)

ENVIRONMENTAL

ACCELERATION LIMITS (in any direction)		
Static	g	1000
Sinusoidal	g	1000, below 2000 Hz
Shock	g	2500 half-sine pulse, 250 µs or longer
TEMPERATURE		
Operating	°F (°C)	-10 to +150 (-23 to +66)
Non-Operating	°F (°C)	-100 to +300 (-73 to +149)
HUMIDITY		Sealed by epoxy

CALIBRATION DATA SUPPLIED
(at 75°F [24°C] and 10.00 Vdc excitation)

FREQUENCY RESPONSE	% plot 20-2000 Hz, dB plot through resonance
SENSITIVITY (at 100 Hz)	mV/g
ZERO MEASURAND OUTPUT	mV
MAXIMUM TRANSVERSE SENSITIVITY	% of calibrated sensitivity
MOUNTED RESONANT FREQUENCY	Hz
INPUT AND OUTPUT RESISTANCE	Ω


NOT IDENTIFICATION
CUT OUT FOR CLAMPING 6 CONDUCTOR SHIELDED CABLE. TYPICAL FOR BOTH COVERS
COVER PLATE (18006 COVER PLATE SHOWN)
SENSITIVE AXIS
10-32UNF-2B THREAD
SCHEMATIC
CENTER OF SEISMIC MASS
INPUT (RED) (WHT RED)
OUTPUT (GRN) (WHT GRN)
INPUT (BLK)
OUTPUT (WHT)
UNIT SERIAL NO.
CUT OUT FOR CLAMPING 6 CONDUCTOR SHIELDED CABLE. TYPICAL FOR BOTH COVERS

NOTES

[1]Sensitivity of 0.20 ± 3% mV/g is available on special order. Accelerometer sensitivity decreases approximately 4% per 100 ft. (30.48 m) of cable. Standardized sensitivity is available with cable length to 25 ft. (7.62 m), maximum. Longer lengths require use of power supplies with external sensing capability, and appropriate special cable.

[2]In shock measurements, minimum pulse duration for half sine or triangular pulses should exceed 0.25 milliseconds to avoid excessive high frequency ringing. (See Endevco Piezoelectric Accelerometer Manual).

[3]Thermal Zero Shift millivolts specified are at -10°/+150°F (-23°/+66°C), reference +75°F (+24°C).

[4]Rated excitation is 10.0 Vdc. The strain gage elements have a positive temperature coefficient of resistance of approximately 0.5% per °F.

[5]Other excitation voltages may be used to 15.0 Vdc, but should be specified at time of order to obtain a more accurate calibration. Warmup time to meet all specifications is one minute, maximum. Endevco Model 106/109 Signal Conditioner is recommended as the excitation source.

[6]Measurand at approximately 1 Vdc. Bridge resistance increases with applied voltage.

[7]Shield of cable should be clamped to case, or case grounded to shield sensing elements.

[8]Transverse sensitivity of 1% available on special order ("T" option).

ACCESSORIES INCLUDED

Model 2981-3 Mounting Stud; Cover Plate and EH3 mounting screws; EHM178 Allen wrench.
7231C-750 with 18006 Open Cover

ACCESSORIES OPTIONAL

Model 27551 Closed Cover.
Model 22299 Cable Assembly, 6-conductor, shielded
Model 27542 -1 Red, -2 Blue, -3 White Jackets:Cable Assembly, 4-conductor, shielded.

Continued product improvement necessitates that Endevco reserve the right to modify these specifications without notice. Endevco maintains a program of constant surveillance over all products to ensure a high level of reliability. This program includes attention to reliability factors during product design, the suppport of stringent Quality Control requirements, and compulsory corrective action procedures. These measures, together with conservative specifications have made the name Endevco synonymous with reliability.

ENDEVCO

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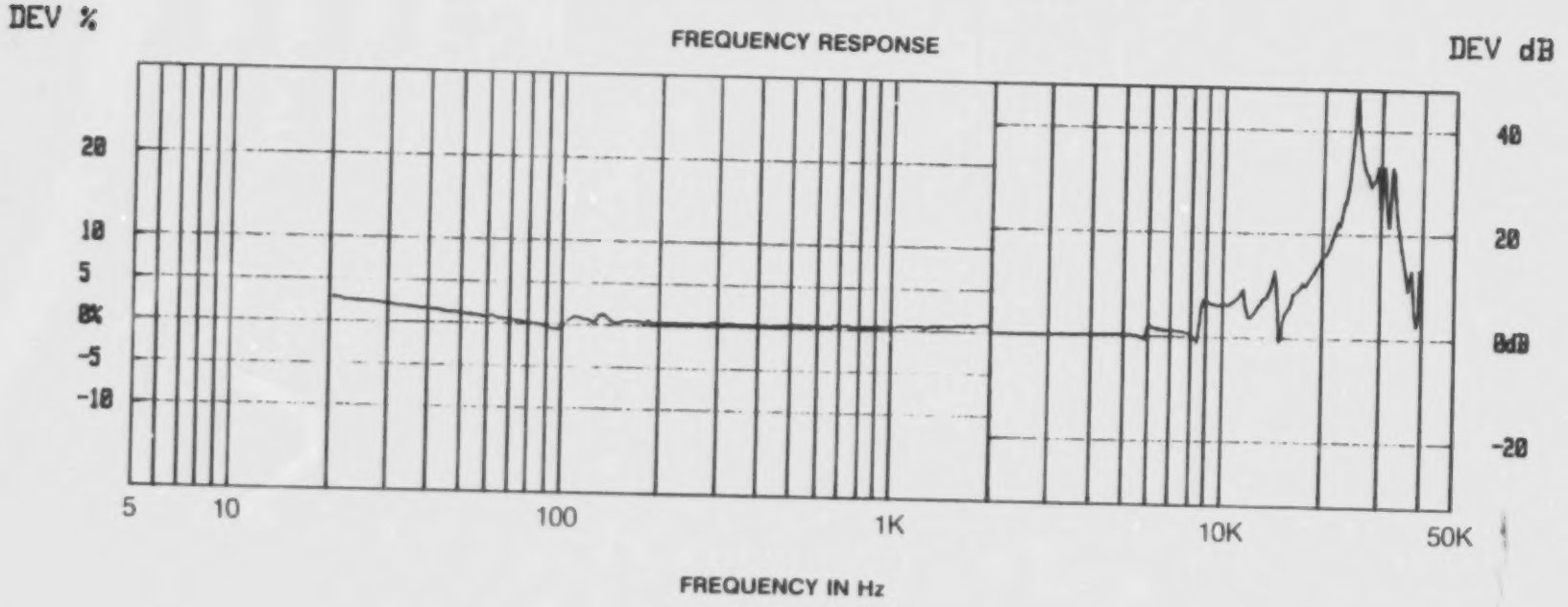
Calibration Data

ACCELEROMETER MODEL 7231C-750 SERIAL NO. EL82

Sensitivity .2372 mV/g @ 100 Hz, 10 g's pK

MAXIMUM TRANSVERSE SENSITIVITY:	1.2 %
EXCITATION	10.814 VDC
ZERO MEASURAND OUTPUT:	-2.4 mVDC
INPUT RESISTANCE	350 OHMS
OUTPUT RESISTANCE	366 OHMS



Date 04/27/88

By A.L

ENDEVCO

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All calibrations are traceable to the National Bureau of Standards and in accordance with MIL-STD-45662. This certifies that this accelerometer meets all the performance, environmental and physical characteristics listed in Endevco® specifications.